CLEAPSS

R142 Equipment and Materials for Environmental Monitoring

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R142 Equipment and Materials for Environmental Monitoring

1. General introduction

A better understanding of the environment and climate and the impact of human activities has never been more important than now. Concern in the past has often focused primarily on natural materials and energy resources available and accessible to mankind in order to sustain and improve life. This remains an important issue, not least because many of the resources of the earth are finite, so effective and efficient recycling as well as further exploration for new sources, has become a major area of development. However, a better understanding of the interactions between the Earth's atmosphere, the seas, lakes and rivers and plant and animal life, and man's impact on them, is now not just important but essential for the survival of the planet and all its life forms.

2. What is environmental datalogging

Environmental datalogging is the recording of relevant information over a period of time. It can be carried out manually, observing experiments first hand, making practical observations and writing them down or it can be done electronically using a datalogger or by other electronic means. This may have a variety of advantages. Being at the site where investigations are taking place may not always be possible for a variety of reasons, not least because the observations may be taking place over a long period of time. Equally the experiment may require very short intervals between readings and it may not be physically possible to make the observations and record them in the very short time span needed. Electronic dataloggers enable both these extreme situations to be met as well as the more routine investigations that require readings to be taken at more manageable intervals. Additionally, many investigations are most readily interpreted by plotting a graph of the results. It is usually possible for the software that accompanies dataloggers to plot and draw the graph for you thus freeing time for discussion and interpretation. There will be times, however when it is precisely those graph drawing skills that are a major part of the aims of the activity in which case it would simply be the tabulated results that would be used.

A datalogger is simply an electronic device into which a range of different sensors can be plugged in order to take observations of environmental parameters. Many dataloggers are in effect small computers and some are now so sophisticated that they can not only record data but also store it and analyse it. Others record and save data but need to be connected to a computer, the data downloaded at a convenient time and then analysed. Interfaces can not store data themselves and must be connected to a computer to record, store and interpret observations. Many loggers, though not all, have their own display. Very recent technological developments offer even more options. A different approach has been developed using software which modifies Microsoft® Excel on a PC, laptop or mini notebook enabling it to be used to pick up and display data collected directly via new USB sensors.

3. Scope and organisation of the guide

Scientific studies of the environment, investigating pollution and work in ecology are an essential part of the school science curriculum. The essential National Curriculum requirements for Key Stage 2 have been included in this guide to encourage secondary schools to build on what the pupils have learned in their primary science lessons.

This guide includes the following:

- an indication of the current requirements of the environmental aspects of the National Curriculum and of external examination boards,
- information on the range of environmental parameters on which measurements can be taken,
- a general discussion of points to be considered in choosing the most appropriate equipment for the requirements of a school or college,
- information on taking measurements of various environmental parameters,
- an evaluation of a range of sensors and dataloggers.

This guide will consider equipment that can be used to explore a number of environmental parameters, as listed below.

- Carbon dioxide and other aerial gases.
- Conductivity (total dissolved solids and salinity).
- Humidity.
- Light.
- Oxygen, aerial and dissolved.
- pH.
- Soil ions.
- Sound.
- Temperature.
- Ultra-violet radiation.
- Water flow rate.
- Water quality.

R142 will ***not*** discuss *in detail* equipment for measuring air pressure, wind speed, rain fall etc, involved in studies of meteorology.

Reference should also be made to sections 17.2 and 17.3 of the *Laboratory Handbook* which discuss the measurement of environmental parameters by electronic and non-electronic methods. The *Handbook* material describes various tests not included in this guide and also gives background information on some of the theory behind the operation of the apparatus discussed in R142. Most measurements will be made using a datalogger or a specialised meter such as a pH meter but in some cases a chemical test may be involved and readings are then typically made by matching coloured reactants against a standard colour scale or recording the number of tablets or volume of chemicals used to reach an end point.

Items of apparatus selected for discussion in guide R142 have been chosen on the basis of their price, their availability as indicated by their inclusion in catalogues of educational equipment suppliers, their suitability or otherwise for use in the field and their availability for loan from suppliers. More expensive items of equipment have not been included unless cheaper alternatives are not available. Most modern dataloggers and many meters have been designed for use in both laboratory work and in the field. The dataloggers tested can usually be operated using mains electrical supply or can be battery-powered and can be taken out of doors for taking environmental measurements. Batteries for such instruments will typically operate for a full day's work in the field without recharging. *With all battery-powered instruments, it is important to remove the batteries or cells from the equipment when not in use for an extended period of time and in storage*.

4. National curriculum and examination board requirements

National Curriculum requirements

The National Curriculum includes investigations of the environment and use of ICT in Key Stages 1 and 2 and subsequent work should be a further development of these early studies especially since many primary schools now use simple versions of dataloggers.

Specifically **Science at Key Stage 2** refers to the following:

Sc1 Scientific enquiry

Ideas and evidence

Pupils should be taught

1a. to try to explain how living and non-living things work and to establish links between causes and effects,

1b. to test ideas using evidence from observation and measurement.

Investigative skills

Pupils should be taught to

2f. make systematic observations and measurements, including the use of ICT for datalogging,

2g. check observations and measurements by repeating them where appropriate,

2h. use a wide range of methods, including diagrams, drawings, tables, bar charts, line graphs and ICT to communicate data in an appropriate and systematic manner.

Breadth of study

1. During the key stage pupils should be taught the knowledge, skills and understanding through:
    a. a range of domestic and environmental contexts that are familiar & of interest to them,
    c. using a range of sources of information and data including ICT-based sources,
    d. using first-hand and secondary data to carry out a range of scientific investigations including complete investigations.
2. During the key stage pupils should be taught to:
    a. use appropriate scientific language and terms, including SI units of measurement to communicate ideas and explain the behaviour of living things, materials, phenomena and processes,
    b. recognise that there are hazards in living things, materials and physical processes and assess risks and take action to reduce risks to themselves and others.

Science at Key Stage 3

1. Key concepts

1.1 Scientific thinking

a. Using scientific ideas and models to explain phenomena and developing them creatively to generate and test theories,

b. Critically analysing and evaluating evidence from observations and experiments.

2. Key processes

- *Practical and enquiry skills*

  Pupils should be able to:

  a. use a variety of methods and techniques to develop and test ideas and explanations,

  b. assess risk and work safely in the laboratory, field and workplace.

- *Critical understanding of evidence*

  Pupils should be able to:

  a. obtain record and analyse data from a wide range of primary and secondary sources, including ICT sources, and use their findings to provide evidence for scientific explanations. (Primary sources such as datalogging and secondary sources such as the Internet are essential aspects of pupils' experience of science).

2.3 Communication

Pupils should be able to:

a. use appropriate methods, including ICT, to communicate scientific information and contribute to presentations and discussions about scientific issues.

3.4 The environment, Earth and universe

The study of science should include awareness that:

c. human activity and natural processes can lead to changes in the environment.

4. Curriculum opportunities

The curriculum should provide opportunities for pupils to:

d. study science in local, national and global contexts, and appreciate the connections between these,

g. recognise the importance of sustainability in scientific and technological developments.

Science at Key Stage 4

How science works

Data, evidence, theories and explanations

1. Pupils should be taught:

a. how scientific data can be collected and analysed,

b. how interpretation of data, using creative thought provides evidence to test ideas and develop theories.

Practical and enquiry skills

2. Pupils should be taught to:

b. collect data from primary or secondary sources, including ICT sources and tools,

d. evaluate methods of collection of data & consider their validity & reliability as evidence.

Communication skills

3. Pupils should be taught to:

a. recall, analyse, interpret, apply and question scientific information or ideas,

c. present information, develop an argument and draw a conclusion, using scientific, technical and mathematical language, conventions and symbols and ICT tools.

Breadth of study

5. Organisms and health

In their study of science, the following should be covered:

a. organisms are adapted to their environment.

8. Environment, Earth and universe

a. the effect of human activity on the environment can be assessed using living and non-living indicators.

GCSE Science subjects

Environmental studies are an integral part of GCSE courses. The four major examination boards in England and Wales are required to produce their GCSE examination courses in line with the QCA specifications. New courses in the sciences were introduced for first teaching in 2006; most other subjects start in 2009. The scientific study of environmental issues occurs to different extents in each suite of sciences produced by the examination boards. Suffice to say that environmental issues are an essential aspect of most of these courses and the use of dataloggers, sensors and appropriate software in collecting data, analysing it and producing relevant charts and/or graphs is made explicit.

GCE A and AS level Science subjects

Similar expectations regarding the use of dataloggers, sensors and relevant software apply to more advanced studies in biological and environmental science. As before the precise wording varies from board to board and subject to subject.

5. Choosing the ‘right’ type of equipment

There is a wide range of different kinds of resource for making environmental measurements This increases the difficulty in making ‘correct’ choices in deciding what equipment to purchase. For example, it is possible to use a purpose-built meter to study one specific environmental factor and a wide range of such meters is available. Additionally some meters have multiple purposes thus enabling several environmental parameters to be studied with the same equipment. It is no longer possible to easily purchase test centres that can be used to measure a number of different environmental variables. Increasingly common in the field of environmental investigations are dataloggers used in conjunction with sensors. The range of dataloggers is also quite wide and more companies are entering the market. As noted above even more recent is the introduction of the USB sensor and software which modifies Excel thus facilitating its use in analysing and presenting data collected via the sensors.

This section considers the background to deciding which of the different ways in which environmental measurements can be approached is best for your school. Section 7 deals with specific factors that should be taken into account when deciding on a specific type of datalogger.

5.1 Purpose-built meters for measuring single or multiple environmental factors

Independent meters are probably more familiar to many teachers and schools may have some of these in stock – an important financial consideration.

Single purpose environmental meters have been around a long time and often have the advantage of being easy to use and relatively inexpensive. Many of the advantages of single purpose individual meters also apply to dual-purpose meters. A meter able to monitor two or more parameters may be less expensive than the total cost of separate individual meters for making the same environmental measurements but flexibility in use by different pupils is also reduced. Being able to measure, say, light as well as temperature may be a distraction for pupils when they only need to monitor one of these factors. In addition, multifunction scales on analogue multipurpose meters may confuse some pupils. Temperature readings are also sometimes included as an additional feature on meters for parameters such as pH, relative humidity or conductivity, in which automatic temperature compensation is built in. In many cases, however, a separate environmental thermometer unit will still be needed because of the absence of a suitable probe for measuring temperature.

Nevertheless should a school decide that individual meters are the best approach it may be helpful to know that CLEAPSS has produced guides on a number of single purpose meters including pH meters, conductivity meters, ammeters and voltmeters, colorimeters and so on in recent years.

5.2 Analogue or digital meters?

Analogue meters with a needle moving over a scale may be difficult for some students to read and, depending on the length of the scale, may not be able to give readings with as great a resolution as the display of a digital meter. They may also be perceived by students as ‘low-tech’ equipment. Nevertheless, for parameters that vary over a wide range, an analogue meter often gives a clearer visual impression of the extent of the changes that are being measured. For example, if a digital meter gives readings of a parameter of 0.45 and 0.89 units, pupils may not see that the measurement has doubled as clearly as they might with a pointer moving twice as far over a scale. Also, for situations in which readings with small continuous fluctuations are obtained, the slight movement of the needle on an analogue meter is often easily ignored, whereas the constantly changing characters of a digital display, especially one showing decimal figures, can be very distracting.

Digital displays look modern, are usually very easy to read and, if the characters are large, can be read by several students at the same time. Digital meters are also more robust, with less chance of damage if knocked or dropped. They often permit greater resolution in measurements but this may not always be advantageous. For example, in monitoring pH changes, measurements to two decimal places will be quite unnecessary; [teachers can, of course, blank off the last digit(s) with paint or tape]. Another disadvantage of digital meters with one or more decimal figures displayed is the impression of greater accuracy that may be conveyed; this is often not deserved. However, this becomes a largely academic consideration if schools opt to use dataloggers on which the readings are digital.

5.3 Meters or chemical test kits?

For some measurements of parameters in soil and water, there may be a choice between the use of sensors, meters or chemical test kits. The latter may have certain advantages, e.g. a test kit is less expensive than the equivalent sensor or meter or the chemistry involved may be of interest. However, replacement chemicals will be needed, perhaps very regularly if the shelf life of the reagents is short. Also, because chemical test kits often rely on the subjective matching of colours, it may be more difficult to obtain precise values of a parameter than with a meter.

5.4 Sensormeters or sensors linked to dataloggers?

As section 4 indicated, changes to the National Curriculum and examination board syllabuses have led to a requirement to make increasing use of ICT in science work in schools and colleges. This has resulted in a wider spread use of dataloggers in general, and for exploring environmental factors in particular. Take up has been inconsistent however. Schools should, therefore, consider their current and future involvement in such ICT work across the science curriculum, and possibly more widely in the school, before investing in new apparatus whether it is to be meter-based or sensor-based. Many meters cannot be used for datalogging, though some provide a suitable output signal permitting connection to a separate datalogger. Philip Harris, for example, developed a range of SensorMeters that provide the function of a meter and the capability to link to a logger in one unit; such instruments obviously provide greater versatility. However, a meter may not be recognised by a given datalogger so the use of purpose-built sensors will make the task of using the datalogger and accompanying software much more accessible and reliable. Sensors designed specifically for use with dataloggers do not normally provide facilities for obtaining direct readings while 'in the field' unless connected to a 'pocket-book' computer or a 0 - 1 V voltmeter is attached.

Schools may decide that there are educational advantages to using meters with inbuilt sensors (or linked to suitable sensors) to measure environmental changes over moderate periods of time, noting readings down and analysing them 'at leisure'. This certainly takes students through the stages of the process more systematically but it also presents greater demands on perseverance and the time needed to complete measurements and analyse them (especially when problems are encountered). It is also much more difficult to use a simple meter and sensor to follow very rapid changes or ones which take place over a longer period of time (such as a full day or more). By contrast most dataloggers linked to appropriate sensors now have the facility to take readings at very short or very long intervals. Most also incorporate a mini-computer which will collate and save the data recorded in tabular or graphical form and carry out detailed analyses on the spot.

Clearly to ensure the effective and efficient use of dataloggers, especially in 'the field', teachers and students need to become familiar with the operation of the datalogger plus associated computer and software in advance.

5.5 USB sensors linked to a computer

At the end of 2008 software was developed which would enable direct plug-in USB sensors to send data directly into any version of Excel spreadsheets and be tabulated, graphed and analysed.

This approach, when further developed, would limit the costs to those associated with the software and the USB sensors. At present only a limited range of sensors is available, though this will probably be expanded. The requirement to link the sensors to a PC, laptop or mini notebook also limits the range of activities that can be carried out and would make remote datalogging extremely difficult.

5.6 Reliability and ease of use

Monitoring equipment ideally should be able to give accurate readings quickly, with the minimum of fuss, every time it is used. Sensors for many parameters work quickly and without problems. Unfortunately, sensors used for the measurement of some parameters, including conductivity, pH and oxygen, often require calibration, either before the instrument (meter or sensor) is taken outside or even in use in the field. The maintenance of electrodes between tests to keep them in good working order must also be considered. The battery compartment of some environmental meters is easily accessible, usually just by sliding back a plastic cover. This ready accessibility may be a disadvantage for work with some pupils; an increasing number of meters have batteries that can only be reached by unscrewing a cover. Pupil accessibility of pre-set calibration controls may also be a problem and some meters have been designed with this potential problem in mind.

6. Measuring environmental parameters

6.1 Measuring conductivity

Measurements of the conductivity of water samples can give an indication of their purity or, more appropriately, the level of dissolved substances in the water. The greater the quantity of substances dissolved in a water sample, the higher the sample's conductivity reading. Conductivity measurements do not, however, give any clue to the *identity* of the dissolved substances. In sea water, readings will usually indicate salinity; in unpolluted water an indication of water hardness may be obtained from conductivity measurements. The conductivity of soils might also provide an indication of levels of soluble nutrient ions that are present.

Measurements in a river *might* indicate the level of pollution but it is impossible to differentiate between pollutants and naturally occurring substances. Thus a comparison of conductivity readings obtained from two separate bodies of water will not always reveal meaningful information. Variations could merely reflect the different nature of the underlying substrate over which the waters flow and hence differences in the nature of the ions that are dissolved in the water. However, if readings are made using water samples taken, for example, at different positions along the length of a stream then rapid changes in conductivity might be used to locate the source of an outflow of chemicals.

Units of measurement

Conductivity sensors or meters often give readings in the preferred units, S cm^{-1} (usually µS or mS) [S = siemens] but Ω^{-1} cm^{-1} [Ω = ohms] may be used. Occasionally, reference may be made to the unit mho (= ohm^{-1}). To add to the confusion, some instruments express the conductivity of solutions as 'total dissolved solids' (TDS), with units of parts per million (PPM = mg $litre^{-1}$) or parts per thousand (PPT); [as a rough guide, PPM = µS × 0.71]. Finally, salinity may be measured in g $litre^{-1}$ of NaCl!

Calibration and use in the field

Conductivity measurements are affected by temperature and although many sensors and meters have automatic temperature compensation, calibration should, for complete accuracy, be carried out with solutions at 25 °C. This could cause difficulties in the field. Calibration of the electrode is therefore best carried out in the laboratory just before the instrument is used. This involves using potassium chloride solutions of known concentration and sensors and electrodes normally carry a clear set of instructions. Solutions can be purchased (or are sometimes supplied with the meter) but can also be made up in school. Table 1 gives some suggested figures for the preparation of KCl solutions of different conductivities.

Table 1 Conductivity calibration solutions

Conductivity of solution (µS)	KCl (g $litre^{-1}$)
1400	0.744
3000	1.678
5000	2.833
7000	4.026
10000	5.741

Meters with integral electrodes will often be permanently damaged if completely submerged or dropped into water. Tests are therefore best carried out on samples of water in appropriate containers, rather than taking readings in situ. Also, since the conductivity measurement of a solution is influenced by the cross-sectional area of the sample, all comparative readings *must* be carried out with the sample in a standard beaker or other container.

Where there is a choice of conductivity electrode available, it is wise to choose a plastic-body version for use in the field.

Ease of taking readings

If a school opts to purchase a conductivity meter then it should be noted that these usually give a simple, direct reading. Others, however, require that the meter reading is multiplied by the setting of the range switch and often also the cell constant of the electrode in use. This may be 1.0 or very nearly 1.0 and so poses few problems of obtaining meaningful readings immediately. The cell constant of an electrode may, however, be more than 1.0 or, with a special electrode used to extend the range of the meter, have a value of 10. Some students may be confused by this additional complication.

Conductivity is strongly temperature-dependent so some equipment may have automatic temperature compensation as a built-in facility. If not, care must be taken to allow for variations in temperature when comparing readings. For each degree C increase there is an approximate 2% rise in conductivity.

Conductivity electrode maintenance

Sheathed electrodes should be replaced in the sheath. Unsheathed electrodes must be kept clean and preferably stored in deionised or distilled water; this may create some problems for transport out into the field. After each use the electrode tip should be thoroughly rinsed in deionised water. Solids should be removed with a small brush such as a toothbrush. If readings become low and erratic, the cell may need replatinisation; refer to the *Laboratory Handbook* section 17.3.2. For some instruments, the cell is an integral unit and maintenance may be difficult.

What to buy?

As is shown in Table 2, conductivity readings for water samples from a pure stream or a seashore rock pool are so different that separate electrodes may be needed if a wide range of conductivity measurements is anticipated.

Table 2 Conductivity readings for various water samples

Sample	Approximate conductivity
Deionised water	0.2 - 1 μS cm^{-1}
Pure stream water	5 μS cm^{-1}
Tap water	50 - 500 μS cm^{-1}
River water	1 mS cm^{-1}
Sea water	> 50 mS cm^{-1}

With meters that will measure only up to 10^{-2} S cm^{-1} and also have a separate electrode, it may, however, be possible to extend the range of the instrument by using a probe with a high cell constant (10.0) and so monitor salt water as well as fresh water. For further technical background info on conductivity see section 17.3.2 of the *Laboratory Handbook*.

6.2 Measuring humidity

Humidity sensors may have advantages over single purpose meters for measuring relative humidity (often described as hygrometers or thermo-hygrometers when they also measure temperature). Some of the latter have a separate external probe but many have the humidity detector built into the meter housing; this could limit the ability to take readings in awkward places. This is not so much a problem for humidity sensors. The sensors of some humidity meters are very delicate and must not become wet; not a particularly desirable feature for fieldwork near streams and ponds with wayward pupils! Sensors may be destroyed by vapours from organic chemicals so safe storage of the equipment away from such chemicals is important. Some humidity sensors work best only in a moving current of air so measurements in confined or enclosed places may pose difficulties. Response times are sometimes very slow, necessitating leaving the sensor in place for an extended period. For further information on humidity, refer to sections 17.2.1 and 17.3.2 of the *Laboratory Handbook*.

Before investing in a meter or sensor to measure relative humidity, it is worth considering whether an approximate indication of humidity levels using an inexpensive paper hygrometer might give sufficient accuracy. Another possibility is the use of cobalt thiocyanate papers (which give a more distinct colour change than cobalt chloride papers, going from blue to pink with increasing humidity).

6.3 Measuring light

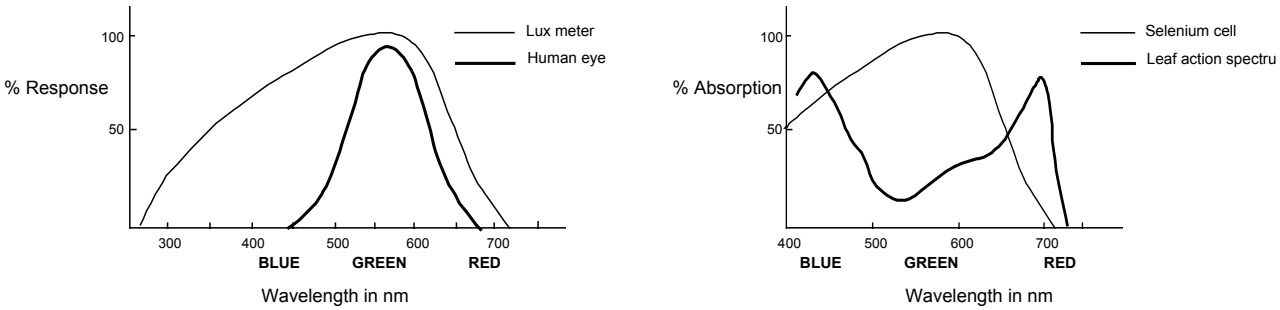
Measurements of light in the field would seem to be a simple matter: point the light-sensing device in one location and take a reading; repeat this at another location and compare results. Differences in readings can then be related to differences in plant growth, animal distribution, etc. Unfortunately, this apparent simplicity is deceptive.

Traps for the unwary

Plants absorb light most strongly in the red and blue parts of the visible spectrum; a light meter may be most sensitive to light in the green region. Animals may be influenced more by red, infra-red or ultra-violet wavelengths; light meters may not respond much to wavelengths at the extremes of the spectrum.

Most light sensors and meters that are now available measure in lux (lumens m^{-2}). They have sometimes been designed for use by lighting engineers to measure light levels in offices, etc, where human perceptions of light are important. Such lux meters typically have a response to the quality and quantity of light that matches that of the human eye (with greater weightings for green wavelengths); see the figure below which shows the spectral response of a typical light meter compared with the human eye. They are not, therefore, ideal for fieldwork, particularly for measuring light beneath trees. Here, red and blue wavelengths will have been absorbed by leaves with much green light remaining. A lux meter will indicate higher light levels than are actually available for plants at ground level to use.

If the action spectrum of a typical plant, showing the absorption of wavelengths by chlorophylls, is compared with the response of a selenium cell used in many lux meters, it is very evident that readings with such a light meter in relation to a plant's ability to photosynthesise must be interpreted with care.



Light levels can vary enormously by a factor of 100,000. In order to cope with this wide variation most sensors use a logarithmic scale so that an output increase of, say, 0.2 volts could represent a tenfold increase in light level. Instruments which measure total radiant energy (irradiance; units - watts m^{-2}) have a more even response across the spectrum but they are unfortunately too expensive for normal school use (and have limitations for fieldwork too). Many suppliers offer sensors that focus on a particular light range but most have an all-purpose light or lux sensor that may cover a range of, say, 0 to 100,000 lux, which may cover a spectral range of 400 to perhaps 1,100 nm.

Note that photographic light meters use a logarithmic scale with no apparent units and indicate the aperture or 'f' number for exposure of film. It is possible to convert such readings roughly to lux or W m^{-2} (see Table 17.6 in the *Laboratory Handbook*). Note too that an increase in exposure of one stop or 'exposure value' represents a halving of illumination. When using a photographic light meter, readings should be taken, at a standard distance, of light reflected off a 'grey card'; the blue cover of a paper copy of a CLEAPSS guide will be suitable for most purposes.

Light readings taken at a single moment may not reflect accurately the amount of light received by plants and animals because of broken or changing cloud cover. The sun going behind a cloud may lead to a light level change of more than a factor of 10, for example. Levels of irradiance increase and then decrease from morning to evening. It is therefore important to take several readings at different times if possible. This is a situation in which the use of a sensor and datalogger over an extended period is particularly valuable.

6.4 Measuring oxygen

Users of sensors or meters for measuring oxygen, either in air or dissolved in water, must be prepared to spend some time calibrating the instrument *each time they wish to take a set of readings.* It may even be necessary to remake the electrode. Although, with care, reasonable results can be obtained, there are many factors that may interfere to produce difficulties. Chemical methods of measuring dissolved oxygen levels, although somewhat laborious to use, can often give more reliable results. For a discussion of chemical tests, see section 17.2.3 of the *Laboratory Handbook*. Chemical test kits provide an alternative. See also the Recipe Card for Winkler's method.

Problems likely to be encountered

An extensive discussion of the problems of using different types of oxygen electrodes is given in section 17.3.8 of the *Laboratory Handbook*; this is **important reading**! It is, however, worth briefly mentioning the important points here.

- Readings are affected by temperature; as this rises, less oxygen is dissolved in water but an electrode usually becomes more sensitive; the two effects, to some extent, compensate for each other. Always try to take readings at the same temperature; if this is not possible, corrections must be made. Section 20.6.7 of the *Laboratory Handbook* gives a table showing how the concentration of dissolved oxygen varies with temperature.
- Readings may be affected by the presence of chloride ions, so measurements of oxygen levels in rock pools need adjustment.
- Readings are affected by pressure changes; it is therefore difficult to take measurements at a wide range of different depths of water.
- Electrodes must be stirred in the samples of water being tested since they use up oxygen and deplete levels in the water immediately adjacent to the probe. If water is not stirred, the readings decrease, often dramatically. Stirring the water may, however, create problems by causing oxygen to dissolve into the water from the air! Stirring actions should therefore be slow, constant and not unduly agitate the surface of the water. In the lab, a magnetic stirrer is helpful. The need for stirring is a significant problem if an oxygen electrode is to be left in a pond over an extended period to take readings with a datalogger. Electrodes may be affected by turbulence in fast-flowing streams and shielding may be needed. Here, however, the local depletion of oxygen from the surrounding water will not be a problem. Ensure air bubbles are not trapped against the electrode membrane.
- The performance of a galvanic probe is sluggish, so several minutes of stirring are needed before readings are taken.

Electrode replacement

There are several electrodes that are used with the variety of dissolved oxygen sensors available at prices schools can typically afford. These are usually either a galvanic or a polyographic design made by companies such as Uniprobe or Russell. The membrane used is most commonly Teflon and is now much more easily replaced. Typically spare membranes are provided by the dissolved oxygen probe supplier: these are filled with the electrolyte and screwed back in place.

Calibration of oxygen sensors (probes)

There are different varieties of dissolved oxygen probes. Some are based on a Clarke cell principle using a KCl electrolyte in a semi-permeable membrane. Temperature variation occurs in at least two ways - oxygen diffusion across the membrane and the solubility of oxygen in the solution. These may, in part, be compensated for by the instrument. Instructions for calibration are usually given with the oxygen sensor and a full discussion in section 17.8.3 of the *Handbook*. It should be noted that the terminals of a galvanic electrode must be shorted together when not in use to prevent a build up of oxygen in the electrolyte. After being remade, a galvanic electrode will need to be 'reconditioned' to remove internal oxygen by storing in (3 or 6%) sodium sulfite solution for 6+ hours before use.

Storage of oxygen sensors (probes)

The electrolyte must be replenished at regular intervals. The cathode tip must not be scratched and the membrane must be kept intact. It is not feasible to use an electrode for measurements at depth. The best arrangement is to collect water in a device as illustrated in section 17.2.3 of the *Handbook* and to take measurements *immediately* once the water samples have been brought to the surface.

6.5 Measuring pH

Discussion of the use of pH meters and electrodes is given in section 17.3.9 of the *Laboratory Handbook*. Most of this applies equally to sensors. There is also useful information in guide R35 *pH Measurement*. There are, however, specific matters that relate to fieldwork that must be considered.

Problems of measuring pH in the field

pH measurements made in the lab are normally performed on reasonably concentrated solutions which have some natural buffering action; they are not unduly changed in pH by contamination with impurities or by indicators used. Water samples, particularly if quite pure, will not behave like this and a slight impurity can change the pH reading significantly. Indicators that are used to show the pH can affect the results and contamination of electrodes can introduce large errors. Carbon dioxide from the air or alkali from glass vessels may all too easily alter the pH of natural water samples.

The following points are essential for reliable and accurate work in the field with a pH sensor electrode with adapter.

- The probe must always be stored and transported in distilled water or pH 7 buffer solution.
- To avoid contamination, scrupulous care must be taken to clean the electrode in distilled water before any measurement.
- Calibration of the meter with a known buffer solution is best done as near as possible to the time of measurement and, ideally, a buffer or buffers close in pH to the value(s) to be measured should be used for this calibration.
- Also important is the need to protect the socket on the meter into which the electrode is plugged from contamination with water, soil and other debris when a datalogger or meter is used outside.

All of these requirements for improved accuracy make pH measurement in the field more difficult and require the careful transport of additional items to the site.

pH values are affected by changes in temperature and unless equipment with automatic temperature compensation is used, corrections will be needed, particularly if all readings are not made at the same temperature. Section 20.6.8 of the *Handbook* gives a table showing how pH varies with temperature.

Selecting the correct pH electrode

Glass electrodes are very delicate and for fieldwork it is sensible to choose a plastic-bodied version which will be a little sturdier. If the pH of soil is to be measured then a special spear electrode must be used and this pushed gently into the soil. There are certain models of separate pH sensors and meters, specifically designed for horticultural use, which employ a metal probe for soil pH measurements. A pH electrode for taking readings in water also uses this type of electrode. These instruments lack the accuracy of meters using glass electrodes. Some suppliers provide a general-purpose electrode and one suitable for low conductivity solutions. If measurements of the pH of acid rain are contemplated, a special electrode is required for accurate work but these are quite expensive.

Calibration of pH electrodes (probes)

Suppliers usually provide detailed instructions about calibration but this usually involves use of two or three standardised buffer solutions to adjust the sensor readings. The choice of these buffers may vary with the temperature of planned usage.

Storage and maintenance of oxygen sensors (probes)

The level of pH electrode storage must be maintained and the pH sensitive membrane must be kept wet. The glass bulb may be cleaned with 0.1 M HCl for 10 minutes or so and then rinsed thoroughly in distilled water before immersing in the storage solution again.

Using indicators to measure pH

Because of the difficulties involved in using pH meters for field measurements, the use of indicator solutions and papers may often be less problematical, though the indicator itself may affect the readings obtained. Indicator solution is commonly used for soil and water pH measurements and there are a number of kits available. For pH measurements in water, indicator paper strips must be left in place for a long time to obtain accurate results and the indicator tends to be leached out of the paper unless the non-bleeding type is used.

6.6 Measuring soil water content and ions

See section 6.5 for a discussion of measuring soil pH. A suitable sensor may be used when carrying out investigations such as bottle biological experiments or the loss of soil moisture by evaporation or the evaluation of the optimum moisture content for growing various species. Such investigations are based on measurement of the volumetric water content of soil. In simple terms dry soil is made up of minerals and pockets of air. When soil becomes wet or even damp then water starts to fill the air pockets. The volumetric water content will thus be limited by the volume of the air pockets (or pores). Soil moisture sensors do not usually need to be calibrated, especially where it is essentially relative values that are required. This may not apply when very accurate values are required or the soil has a high sand, salt or organic content. Calibration is then usually carried out using either a two point, or the more accurate multiple point, calibration - both of which are lengthy processes. Most soil moisture sensors use capacitance to measure dielectric permittivity of its surroundings. The sensor produces a voltage proportional to the dielectric permittivity of soil, which is a function of the water content. Not all suppliers sell soil moisture sensors.

Measurement of the levels of minerals such as nitrogen, phosphorus and potassium in soils is possible using indicator strips and chemical test kits produced for horticultural use. Various methods are available for measuring the levels of natural or pollutant ions within the soil. Most are performed on soil samples mixed with water and so only measure soluble components of the soil. Clearly the readings only have significance if equal volumes of soil are used. In some instances, the use of tests designed for monitoring river or stream water samples may provide more reliable assessments of water-soluble soil ion contents. See section 17.2.3 in the *Laboratory Handbook*.

Some sensors are designed to test for specific ions. These will be mentioned briefly in Section 8 but tend to be very expensive. Additional information is in section 17.2.2 of the *Laboratory Handbook*.

6.7 Measuring sound

Sound levels are commonly measured in dBA which is a unit, like the lux, that is adjusted to allow for the human perception of sound. dBA is a measure of sound intensity or loudness – the 'A' is a weighting added to a sound pressure value to bring the measure nearer to that of the human ear. This is not normally a problem since studies of sounds in the environment will invariably be in relation to their effect on humans. However, work involving investigations on, say, the sound-related behaviour of bats should not use the dBA unit[1]. See section 17.3.11 of the *Laboratory Handbook* for further details. Table 4 below gives some typical sound levels for comparison.

Table 4 Approximate loudness of sounds

Sound levels	dBA
Pain level	120*
Circular saw at 1 m	110
Loud motor horn at 30 m	100
Office duplicator at 1 m	80
Ordinary conversation at 1 m	70
Ticking of a watch at 1 m	30
Threshold of hearing	0

* This is the level that is dangerous even for short periods; note that lower sound levels may be dangerous if endured for a period.

Many common environmental investigations relate to traffic or aircraft noise so dBA measurements are quite suitable.

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1 A number of instruments capable of detecting the ultrasonic sounds produced by bats are available: schools might consider the use of a 'Batbox Baton' at £60 + VAT + p&p or the more sophisticated 'Batbox III D' at £130.00 + VAT + p&p both from Stag Electronics.

6.8 Measuring temperature

The mercury-in-glass thermometer, although suitable for many applications in the laboratory, is less than ideal for fieldwork. It is easily broken and it is often difficult to take temperature readings in inaccessible locations, for example, at different depths of water (although a maximum / minimum mercury thermometer could be used for such readings). Electronic sensor thermometers would appear to be suitable, alternative instruments. Instruments with probes can easily be pushed into the soil, beneath bark, etc.

The main types of sensors employed in electronic thermometers include thermistors and thermocouples. Resistance thermometer sensors are likely to prove too expensive for most school uses. For a full discussion of the pros and cons of sensor type, and other information on electronic thermometers, refer to section 10.7.3 of the *Laboratory Handbook*.

Table 5 Electronic thermometer sensor types

Sensor	How it works	Suitability for environmental studies
Metal resistance (e.g. platinum)	As the temperature rises, the resistance of the material also rises; a positive temperature coefficient. The change in resistance produces a display via the sensor.	These are accurate but very expensive Resistance thermometers provide greater precision, operating within the range -200 °C to 850 °C.
Semi-conductor thermistors	As the temperature increases, the resistance of the semiconductor material decreases, i.e. a negative temperature coefficient. The change in resistance is registered by the sensor and can be transmitted to give a display.	These are inexpensive to produce and most models used in schools have thermistor probes. They are also widely used in temperature datalogging sensors. The range of temperatures measured is between -50 °C and 200 °C. Thermistor sensors can be quite small and may have low response times which can, in liquids, be better than with mercury-in-glass thermometers.
Thermocouple	A thermocouple measures the difference in temperature between two junctions of dissimilar metals. This gives rise to a voltage which is registered by the sensor and produces a display.	These tend to be more expensive than a liquid-in-glass thermometer. The K-type is the most common. Because of their good thermal conductivity, thermocouples usually have a low response time. Thermocouple systems can cover temperature ranges from -250 °C to beyond 2000 °C.

Some instruments that might seem attractive for environmental monitoring have in fact been designed for the food and hygiene industries and the requirements and rigours of the school laboratory or the field were not a consideration in their design. Some may even still be calibrated in Fahrenheit. Response time might be an important factor for some users. Response times are measured in air from 40 °C to 22 °C and in liquid from 100 °C to 0 °C. There is little to choose between mercury and electronic thermometers in their equilibration times in air. Immersion depth is not usually critical but immersion under 2 cm gives a slower response in liquid.

6.9 Measuring water flow rate

The cheapest method involves the use of ‘Pooh sticks’ and a stopwatch but this lacks scientific credibility and cannot show differences in flow rate at different depths or even at different points across a stream! Instruments available are already calibrated and use the force of water flow to rotate an impeller (or occasionally to move vanes apart). They can be lowered into the water to the required depth but require ready access to the water from the bank of a stream or river, or wading out into the water to position the instrument. Their use therefore has implications for health and safety and for management of fieldwork by students. Suppliers go to great pains to underline this fact, especially in view of the deaths of a number of people in sudden unpredicted water surges.

6.10 Measuring water pollutants

Indications of the level of pollution in water may be obtained by using meters to measure conductivity and/or dissolved oxygen; see sections 6.1 and 6.4 above for details. Chemical tests using indicator strips, comparators or reagent kits are available to measure a wide range of pollutants. Some sensors are designed to identify specific ions such as the ammonium, nitrate, sulfate ions or, as mentioned in 6.6 above, a number of metal ions. These tend to be very expensive and would only be relevant to specific types of environmental investigations. For cost reasons they have not been reviewed in this guide. Further information is included in section 17.2.3 of the *Laboratory Handbook*.

6.11 Measuring ultraviolet radiation

Ultraviolet radiation has wavelengths in the region of 400 to 100 nm which are shorter than visible light but not as short as X rays. There are three main types of UV radiation: UV A, UV B and UV C. All are emitted by the sun but almost all UV C, which is the most harmful to human beings, is absorbed by the earth's atmosphere. Over 98% of the UV radiation reaching the earth is UV A.

Table 6

Type of UV radiation	Approximate wavelength range
UV A	400 – 315 nm
UV B	315 – 280 nm
UV C	280 – 100 nm

There are a number of benefits from UV radiation. Vitamin D production is stimulated by exposure to UV B. Fluorescent lamps produce UV radiation by ionising low-pressure mercury gas. A phosphorescent coating on the tube absorbs the UV radiation and emits visible light. A number of birds, reptiles and insects can see into the near ultraviolet range. A number of fruits, flowers and seeds stand out more strongly at ultraviolet wavelengths. Indeed, the plumage of some more exotic birds stands out more distinctively in this range too.

However, UV radiation also is of environmental concern because it can give rise to skin sunburn or worse to skin cancers on over-exposure to strong sunlight or other sources of UV. The shorter the wavelength the more harmful the effects on human beings. The longer wavelength UV A radiation is also emitted by sunbeds and, although not causing sunburn like UV B, is believed to cause indirect DNA damage when it penetrates the skin. The shorter wavelength UV B can cause sunburn or worse and is of direct danger to DNA. It is also emitted in electric arc welding and acetylene welding. Damage to the outer parts of the eyes, such as photokeratitis and conjunctivitis, can also occur in strong, direct sunlight in snowy conditions as well. The condition known as 'snow blindness' arises from this damage. Protection for the eyes is therefore called for in these conditions or when carrying out welding and similar operations. Weather forecasts frequently include reference to a UV index, usually a number between 0 and 10. Table 7 overleaf indicates the sort of protection that is needed in each of these conditions.

Table 7

UV Index	Description	Sun Protection Required
0 - 2	Low	• Minimal sun protection required for normal activity. • Wear sunglasses on bright days. If outside for more than one hour, cover up and use sunscreen. • Reflection off snow can nearly double UV strength. Wear sunglasses and apply sunscreen.
3 - 5	Moderate	• Take precautions - cover up, wear a hat, sunglasses and sunscreen especially if you will be outside for 30 minutes or more. • Look for shade near midday when the sun is strongest.
6 - 7	High	• Protection required - UV radiation damages the skin and can cause sunburn. • Reduce time in the sun between 11 am and 4 pm and take full precautions - seek shade, cover up, wear a hat, sunglasses and sunscreen.
8 - 10	Very High	• Extra precautions required - unprotected skin will be damaged and can burn quickly. • Avoid the sun between 11 a.m. and 4 p.m. and take full precautions - seek shade, cover up, wear a hat, sunglasses and sunscreen.
11+	Extreme	• Values of 11 or more are exceedingly rare in this country. However, the UV Index can reach 14 or more in the tropics and southern U.S. • Take full precautions. Unprotected skin will be damaged and can burn in minutes. Avoid the sun between 11 a.m. and 4 p.m., cover up, wear a hat, sunglasses and sunscreen. • White sand and other bright surfaces reflect UV radiation and increase UV exposure.

Protection for the skin is now strongly recommended by health professionals and a variety of proprietary brands are available to meet different conditions. Ingredients commonly used include titanium dioxide, zinc oxide and avobenzone. Sunscreen creams are normally classified by a Sunscreen Protection Factor (SPF). This is intended to indicate the level of protection against UV B radiation. Table 8 illustrates this point.

Table 8

SPF	Percentage of UV B absorbed
15	92%
30	96.7%
40	97.5%

More recent research has raised questions about the length of time over which sunscreen protection against UV B remains effective and more investigation is needed.

A number of polymers have also been shown to degrade on exposure to UV radiation and antique paintings may also be discoloured.

Clearly there is much scope for environmental monitoring and investigation in this area. Most sensors used to detect UV radiation available at acceptable prices to schools are designed to measure either UV A or UV B but quite often both together.

Further information is included in *Students Safety Sheets*.

6.12 Measuring aerial gases including carbon dioxide, nitrogen dioxide and sulfur dioxide

Much emphasis has been placed on the role of carbon dioxide and other aerial gases in global warming, so environmental monitoring in schools and colleges is likely to give some emphasis to their study. The average concentration of atmospheric carbon dioxide over the past 40 or so years has increased from about 320 PPM to over 380 PPM, though figures are likely to be higher in localities close to areas of high emissions such as major roads or roundabouts. Carbon dioxide can absorb increasing amounts of infrared radiation and is thus able to act as one of the so-called 'greenhouse' gases, gradually contributing to a raising of atmospheric temperatures.

The carbon dioxide content in air samples may be quantitatively investigated using chemical methods. This involves absorbing the carbon dioxide in an air sample in concentrated potassium hydroxide and titrating against barium hydroxide solution. This can be a lengthy and potentially hazardous procedure but for those interested further information is given in section 17.2.1 of the *Laboratory Handbook*. Much more convenient is the use of carbon dioxide sensors. The nature of the investigations will depend on the range of the enquiry, for example, the variation of carbon dioxide content in air near busy traffic-laden roundabouts compared with open country motorways or side roads. Some useful and interesting investigations can be done by linking GPS tracking with carbon dioxide monitoring. The variation in the carbon dioxide content in air in a classroom or other area over time can be studied as can the change in the levels of carbon dioxide in fermentation processes or in the growth of plants. Carbon dioxide sensors often have a high and a low setting which permit readings approximately in the ranges of 0 to 10,000 or 0 to 100,000 PPM. Many sensors work on monitoring the amount of infrared radiation absorbed by the carbon dioxide molecules. Calibration of such sensors is not usually necessary but they may be sensitive to temperature changes although they normally operate reasonably accurately between 20 °C and 30 °C.

Nitrogen dioxide is produced in vehicle engine emission within a mixture of nitrogen monoxide (nitric oxide) and nitrogen dioxide, often depicted as NOx. These are both toxic and can give rise to asthma attacks in susceptible people. They are a major contributor to acid rain and photochemical smog. A nitrogen dioxide sensor can be used in studies of variations in the levels of the gas in different situations such as near major roads, near side streets and in open countryside. Such sensors will usually detect up between 0 and 10 PPM of nitrogen dioxide. Not all companies produce such sensors and they are relatively expensive.

Sulfur compounds are present in most fossil fuels to a greater or lesser extent. When these are combusted they give rise to sulfur dioxide, which is toxic, can lead to asthma attacks and also gives rise to acid rain. It should also be noted that significant amounts of sulfur dioxide are released into the air from naturally occurring events such as volcanic eruptions. Sensors will usually detect up between 0 and 10 PPM of sulfur dioxide. Not all companies produce such sensors and they are relatively expensive.

7. Factors to consider when choosing systems

Assuming that a school has decided to revise its approach to environmental monitoring and possibly to purchase one or more dataloggers and accompanying sensors, there are still a significant number of factors to take into account. Most are self-evident but a few may not have been taken into consideration. Some of the major ones will probably include:

- cost,
- existing provision for environmental monitoring in the school,
- the approach to be taken to environmental monitoring,
- age range over which the datalogging equipment will be used,
- usage of equipment by other disciplines within the school (thus possibly dividing the cost),
- the use of datalogging equipment across the science department,
- the balance between use in the laboratory and use in the field,
- the on-screen display requirements in the field,
- the balance between pupil practical work and demonstration,
- the location of work in the laboratory.

The reader will no doubt be able to add other factors to be considered before taking crucial and potentially expensive decisions. It is worth highlighting a few issues relating to each of these points.

Cost

The majority of school and college science departments work to a very tight budget. Few can afford to purchase equipment that will sit unused for months on end or is so difficult to use that staff are wary of its use at all. Many companies offer trial use of loggers and often sensors before purchase, thus enabling schools to evaluate ease of use and boosting of confidence before commitment.

Existing provision in the school

Most schools will already have some provision for environmental monitoring, either within the science department or in other departments such as geography. It makes economic sense to consider what existing provision is suitable for continued use and might be compatible with any potential new purchases.

The approach to be taken to environmental monitoring

There are frequently new developments in electronic data capture. One of the newer ones is to avoid use of a datalogger altogether and to employ specially designed software to modify Excel presentation to display sensor collected data. As noted in sections 2, 3 and 5, this approach may reduce some of the costs but needs a laptop or other computer and has implications for the range of activities, including remote logging, which are possible. Schools will need to decide how important this is and how far they wish to invest in new developments.

Age range over which the equipment will be used

It is important that both staff and pupils feel confident in the use of the datalogger and the relevant sensors. Some datalogger programmes have different levels of demand and complexity of presentation. A school or college may plan to include environmental investigations in a number of different age or year groups. Such a facility might therefore be beneficial and should be taken into account when final choices are being made.

Use of datalogging equipment by other disciplines in the school

Other departments, most obviously the geography department, might also be using datalogging systems or wish to do so. The possibility of joint purchase should, therefore, be at least considered, though there are obvious potential snags to such an arrangement, not least possible clashes in timing of use. Some dataloggers have a wide variety of facilities built in so that other less obvious departments might well find them useful, mathematics for example. The use by other disciplines or departments in the school is also likely to affect the range of sensors required. Since the majority of sensors made are not interchangeable between systems, this could be an important issue.

Use of datalogging equipment across the science department

Datalogging is not only a valuable tool in environmental studies. It has a variety of potentially valuable uses in other science disciplines such as chemistry (studying rates of reaction) and physics (studying velocity and acceleration for example). Although a wider range of sensors would need to be purchased these additional uses could make the outlay of a large amount of money more justifiable.

The balance between use in the laboratory and in the field

Some environmental investigations can be carried out in the laboratory but many are clearly more appropriately done in the field. Portability of equipment, usually the sensor(s) and datalogger, becomes a much more significant issue. Although the majority of dataloggers tested have a good battery life, this may be an issue to consider if overnight recharging is a problem or if investigations lasting several days are planned.

The on-screen display requirements in the field

Choice will also be dependent on what range of display is required when in field use. For example, if all that is required is to be able to take readings and record for subsequent analysis, the choice will be different to that required if analysis is required on the spot. The range of on-screen display varies significantly between models.

The balance between pupil use and demonstration

This can be a major issue when considering system purchase. There are some significant variations in price between models considered. Clearly, if a datalogger and sensors are mainly intended for demonstration purposes then a more sophisticated, more expensive model might be preferable. However, if much of the work is likely to be done in the field then a larger number of less expensive models may be the preferred choice.

The location of work in the laboratory

Where investigations are to be laboratory based it is essential that an appropriate range of services is available in the laboratory for the usage planned. So, if work is to be carried out by pupils, electrical points and all other facilities relevant to the investigation, including possible access to a computer, must be suitably located. If the investigation is to be done by demonstration, the laboratory must not only have suitable services and other facilities, such as projection, but also appropriate visibility to all pupils observing.

It is worth reiterating that schools should discuss possible purchase with representatives and suppliers before taking decisions. Further, where possible, **trial packages should be evaluated in the school** situation by staff and pupils concerned.

8. Evaluation of equipment and materials

The ranges and sophistication of electronic equipment on the market for monitoring environmental parameters are continually changing. Although the information in this guide is up-to-date at the time of writing, given the rapid developments in microelectronics and computing, schools and colleges should expect that some of the apparatus described may, in future, be changed for an improved or alternative model or discontinued. It is also possible that totally new approaches to datalogging might be developed. It is also worth checking for possible discounts or special deals that may be offered by companies. Always check with a range of various suppliers before placing an order.

CLEAPSS is very grateful to the companies concerned for the loan of equipment, available to schools and colleges, which is reviewed below and for their help with a number of issues arising. It should be noted that there are a few other dataloggers that may be available for purchase but no samples were provided for the review.

Three aspects have been reviewed for each system: the datalogger, the sensors available (some of which have been tested where they have been available) and the software enabling links to be made to an external computer.

The following factors were used in our evaluation of the dataloggers and this may assist you in evaluating others.

Width, height, depth, weight and availability of a carry case

The physical dimensions of the datalogger and its weight will affect its portability. Larger models will be harder to transport and will require more storage space. Smaller models may be more awkward to operate and may be pocketed or mislaid by pupils. A carry case will make transportation in the field easier, help protect the unit during transport and may make it less likely for the unit to be mislaid or pocketed.

Memory

If the datalogger is to be used in the field or remotely then it must be able to store the data collected. More memory should translate into being able to store more readings - meaning that the sample frequency can be increased or that the duration over which readings are taken can be increased. Also, the readings will need to be saved to computer less frequently. Some dataloggers can save data direct to a memory stick whereas most need to be plugged into a computer to save the data. Some have no memory at all and need to be attached to a computer to store captured data.

Screen size

It is important that data displayed on the datalogger is clear and legible. A large display with large characters is preferable for a demonstration model but data is typically transferred to a computer for display, analysis and discussion back at school. A larger screen is likely to deplete the battery more quickly.

Battery

Battery life is a key factor in the use of a datalogger in general and particularly in remote use and use in the field. Can it be easily recharged overnight? Will the charge last all day out in the field? Are the batteries custom or are they standard batteries that can be easily purchased?

Ports

The type and number of ports may be influential factors in the purchase of a datalogger. How many sensors may be attached at once (and therefore how many parameters may be read simultaneously)? Most connections to a computer will be via USB - if only a serial connection is available then a serial to USB adapter(s) may need to be purchased and installed.

Wireless connection

Typically, dataloggers do not have a wireless connection. Some models have Bluetooth for very short range transfer of data which is likely to be of limited use and is likely to drain battery life more quickly. Some do have true wireless connectivity but provided the unit has enough memory then it is of little value unless you think that you may want to conduct a long term remote study.

Manuals and upgrades

A good, clear and comprehensive manual will be very helpful when it comes to setting up and using the datalogger. Allow yourself sufficient time to read the manual carefully. Software upgrades may be a mixed blessing - they may provide additional functionality or fix problems with the software but are often an undesirable complication.

Weather proofing and field use

General comment about how waterproof the unit may be and how portable and comfortable the unit is to use in the field.

Operation

More detailed information about the functionality and use of the datalogger.

Sensors

Details the range of sensors available for use with the particular datalogger.

Software

Software is often the last consideration if, indeed, it is considered at all. The software must be compatible with your computers and you must have an appropriate licence for the use of the software. Good software should install without complication and should provide the ability to analyse and suitably present the collected data. It is well worth the time and effort required to become familiar with the software and its functionality and use.

8.1 Philip Harris Harris e.log

8.1.1 Harris e.log II datalogger

Width	186 mm at top, 182 mm at bottom
Height	130 mm
Depth	41 mm
Weight	649 g
Memory	4 Mb
Screen size	80 mm by 60 mm (LCD) This gives a reasonably clear picture
Carry case	Not made (although Gratnell tray linings are available)

Ports	Top vertical face - power, 2 USB ports Front vertical face - 4 mini DIN ports for sensors
Battery	e.Log II has two lithium ion rechargeable batteries. These may be charged either from the mains or when connected directly to a computer. Initial charging takes about 8 hours and fully charged the battery will last for about 8 hours depending on the sensors used.
Wireless connection	No facility for Bluetooth connection.
Upgrades	Available through the Internet.
Manual	Quickstart guides and user manuals are provided and are clear.
'Field' use	Although not large, the weight of the e.log II is greater than many other loggers. Nevertheless, carrying and use in the field is not too difficult.
Operation	This datalogger can be used a stand-alone device to record, display and graph data or as an interface to another computer. Installation of the USB driver from CD supplied before charging is easy and quick. Navigation is by keypad. The start screen gives clear choices (set up and run, view saved results, change settings and shut down). Change between screens is simple using an arrow button. Usage is straightforward and the screen is easily restored from screen saver mode. Default sampling is 60 readings at 1 second intervals. Changing these settings to suit the investigation is straightforward. Datalogger auto-recognises a sensor pictorially on the sensor status bar. Up to 4 sensors can be tracked at once. Starting and stopping logging is clear and labelling of experiments uses letter buttons on the case front much as in texting. (An alphanumeric keypad is also available). Screen auto adjusts y axis to appropriate units for several sensors. Various modes are available to match investigations – quickstart (continuous for 0.5 sec), normal, burst (fast log for 1 sec duration for very fast events), snapshot (irregular but labelled intervals) and frugal modes. Delayed starts are offered as an option. Results can be tabulated or graphical. Datastorage (really a must for field or remote use) an option. Data may be saved direct to a memory stick or to a separate computer.

Costs

Supplier	Catalogue number	Price
Philip Harris	B8L 11228	£239.50

8.1.2 Harris e.log II S datalogger

Width	186 mm at top 182 mm at bottom
Height	126 mm
Depth	40 mm
Weight	643 g
Memory	8 Mb (i.e. double the e.log II)
Screen size	73 mm by 55 mm (slightly smaller than the e.log II but still gives a reasonably clear picture)
Carry case	Not made (although Gratnell tray insert available)

Ports	Top vertical face - power, 2 USB ports Front vertical face - 4 small DIN ports for sensors, 2 output ports
Battery	e.log II S has a pair of lithium ion batteries. These may be charged either from the mains or when connected directly to a computer. Initial charging takes about 8 hours. Fully charged the battery will last for about 8 hours in the field depending on the sensors used (some sensors have higher electrical demand than others).
Wireless connection	No facility for Bluetooth connection.
Manual	Quickstart guides and user manuals are provided and are clear.
Upgrades	Available through the Internet.
'Field' use	Although not large, the weight of the e.log II S is greater than many other loggers. Nevertheless, carrying and use in the field, as with the e.log II, is not too difficult.
Operation	Operation is very similar to the e.log II but navigation is controlled by a straightforward, touch screen system. Response time was reasonable but slightly slower and scrolling was also subject to very slight delays.

Costs

Supplier	Catalogue number	Price
Philip Harris	B8L 11239	£342.50

8.1.3 Harris SensorMeters

Philip Harris still produces its SensorMeter devices that have direct digital readouts. These can be used as stand alone SensorMeters or in conjunction with e.log II dataloggers which recognise the Firstsense and SensorMeter ranges. This enables results from these machines to be recorded, displayed and stored in a variety of ways.

8.1.4 Harris sensors

e.log sensors are common to both e.log II dataloggers and are essentially designed ultimately to supersede Firstsense sensors. Older Harris sensors including existing sensor meters can be used with the aid of an adapter; examples suitable for environmental monitoring include conductivity, dissolved oxygen, ultraviolet and possibly high temperatures. This could be useful to schools already possessing such meters especially since the range of e log sensors is rather more restricted at present than from some other suppliers.

Environmental Parameter	Comment
Air pressure	This sensor measures air pressures in the range 850 to 1150 mB (at sea level). It has a satisfactory response time. It can also be used to measure water pressure down to a depth of about 1 m.
Light	Measures on a 0 to 100% scale rather than lux. A collimating device is used to make response very directional. The cadmium sulfide sensor gives spectral response close to that of human eye. Response is suitably rapid for general use but not for sensing rapid changes in light level. Philip Harris does not produce a turbidity probe but this light sensor could be used instead where water studies are involved.
pH	Comes as body and separate detachable probe. In contrast to most pH probes this may be stored dry and can be used without further calibration for basic testing. For greater accuracy wet storage is essential and further calibration using a standard buffer solution is needed.
Relative humidity	The sensor measures relative humidity on a 0 to 100% scale. It gave a reasonably short response time and sensible values on testing.
Sound	Operates over range of 50 to 110 dB. The sensor offers a choice of fast or slow response according to investigational needs via a switch on sensor body. Testing yielded appropriate values.
Temperature	-10 °C to 110 °C This sensor is suitable for use in air or non-corrosive liquids. The sensor element is housed in the tip of a thin stainless steel sheath and gave rapid response to change of location. Also has LED giving colour change from below 60 °C to above 60 °C.

There are a number of other sensors for the logger but they are not relevant to a study of environmental factors but the full range should be taken into account when deciding about which logger and sensors to buy. It is likely that the range of environmental sensors for the e.log II dataloggers will be enhanced so that the range is nearer to that of the SensorMeters.

Costs

Sensor	Supplier	Catalogue number	Cost
Air pressure	Philip Harris	B8L 11368	£69.95
Light	Philip Harris	B8L 11289	£24.75
pH probe	Philip Harris	B8L 12245	£21.25
body		B8L 16342	£56.50
Relative humidity	Philip Harris	B8L 11423	£46.25
Sound	Philip Harris	B8L 11307	£34.50
Temperature	Philip Harris	B8L 11290	£25.95

8.1.5 Harris e.log vision software

Compatibility	All post 98 systems (Windows 2000, XP) but may have problems with VISTA at present.
Licence	Single, multi- and RM network licences available.
Installation and operation	Easy and quick to install. Opening screen offers a menu of new experiment template, a library of existing experiment templates, a saved work link, live WEB or LAN connection, data download from datalogger facility etc. The “new experiment” template enables teachers to create their own template rather than use a prescribed one. The template offers range of apparatus, instructions, result format, etc, all of which can be altered. As with the logger data duration and frequency of sampling can be set for each specific investigation. There is choice of experiment modes as with direct datalogger use – normal, economy, burst, snapshot or quick start. Quick start has a default facility, e.g. for delayed start, relation to a specific event (e.g. nightfall) or some other trigger available. Direct collection of experimental results gives choice of auto-scale or auto-scroll. As with the logger there is a results option of meter (digital or analogue), tabulated or graphical presentation of results. Graphs can be in line, bar, pie, etc, format. The cursor operated toolbar offers the option of finding graph gradient, area, difference and point values, etc. The styles menu offers enhancement of presentation to include headers, table, graph, description, labels, etc.

8.2 Data harvest Easy Sense Q

8.2.1 Data harvest Easy Sense Q Advanced datalogger

Width	180 mm
Height	110 mm
Depth	43 mm
Weight	393 g
Memory	256 Kb
Screen size	74 mm by 24 mm (quite small for easy direct readout)
Carry case	Comes with storage bag. Spare bags can be bought.

Ports	Top vertical face - power socket, 1 USB port, e.g. for link to external computer Front vertical face - 6 mini DIN ports for sensors, two labelled A and B for timing operations
Battery	Rechargeable lithium ion battery. Charging is either from the mains or when connected to computer. Charging takes about 5 hours. The battery should last up to 35 days in Easy Log or remote mode (this depends on which sensors are being used). This should easily exceed most school needs. Users are advised to recharge every 6 - 8 weeks if not in use.
Wireless connection	Some models are Bluetooth enabled allowing transfer of data to a computer no more than 10 metres away. Bluetooth models weren't tested but have greater battery demand.
Manual	Comes with straightforward user manual and Easy Sense quick start guide
Upgrades	Software updates are available from the Data Harvest website
Weather proofing	No datalogger is waterproof. In the field users are advised to store in a plastic or other protective box.
'Field' use	The relatively limited size and weight make it fairly easy to use in the field
Operation	This datalogger can be used a stand-alone device to record, display and graph data or as an interface to another computer. Installation of the USB driver from CD supplied before charging is easy and quick. Navigation is by a four-base keypad. The main menu start screen gives a choice of three levels – for secondary pupils level 2 or 3 should be used. The menu is easily navigated by the up and down buttons. Power saving operates after 2 minutes without use (longer for the Bluetooth model). The menu offers 'easy log', meter, snapshot, logging, time & motion (unlikely to be used in environmental work) and system (plus switch off). Sensors are easily connected via leads (both short and long supplied) and are recognised by the logger. Several sensors can be tracked at the same time (some interference is evident with a pH and an oxygen sensor together). In meter mode readings are taken every half a second but no data is stored. Snapshot mode allows sensor readings to be captured on demand and now the data is readily stored in the memory. Scrolling allows a comment to be added and it was easy to repeat the experiment and identify each run separately. It was also easy to retrieve data. In easy log mode it was possible to permit logging of the desired sensor readings to continue indefinitely. Default sampling is 40 readings per second for 1000 samples after which the sampling rate halves and every other sample is discarded. This process is repeated indefinitely. In logging mode the duration of logging, the frequency and any desired triggers were easily set. Changing these settings to suit the investigation proved to be straightforward. Time & motion mode was not tested but is likely to be of value when using light gates for example. Data may be saved to a separate computer using the Easy sense software.

Data Harvest also produces the Easy Sense Q3 and Q5, which have respectively three and five in-built sensors and two sensor ports. The Q3 is more suited to upper primary classes and the Q5 to upper primary classes, middle schools and lower secondary classes. They are cheaper at around £200.

Costs

Supplier	Catalogue number	Price
Commotion Easy Sense Q3	13202-21	£189.00
Data Harvest Easy Sense Q Advanced	4000	£229
Data Harvest Easy Sense Q Advanced Bluetooth enabled	4001	£258
Data Harvest Easy Sense Q3	5001	£175.00
Data Harvest Easy Sense Q5	5025	£209.00
Scientific & Chemical Easy Sense Advanced	DAT 051 010	£229
Scientific & Chemical Easy Sense Advanced Bluetooth enabled	DAT 051 020	£255
The Consortium Easy Sense Q3	310026	£188.95
TTS Easy Sense Q3	849-ISENSE	£189.00

8.2.2 Data Harvest Smart Q sensors

Environmental Parameter	Comment
Air pressure	The 3140 measures pressure in kPa (range 0 to 110 kPa) or in Hg (0 to 33 in Hg). Tested results matched to other pressure readings with suitable accuracy. Also acts as an altimeter with a range of -500 m to 12,000 m. This was not tested.
Carbon dioxide	The 3152 has a flat cylindrical shape thus facilitating formation of a sealed chamber with e.g. a beaker. It covers two concentration ranges 0 to 10,000 PPM and 0 to 100,000 PPM. The sensor responded quickly and gave sensible figures that reflected typical expected ranges though precise absolute values are difficult to confirm.
Colorimeter	The 3275 offers two ranges (0 to 100% transmission and 0.05 to 1.05 absorption). Red, green, yellow and blue slides and a pack of cuvettes are provided. The tests carried out involved changes in opacity as might be found comparing turbidity in water samples. Results were much in line with those expected. As with many of the sensors, there is a much wider range of uses in scientific investigations, e.g. quantitative analysis of sugars, enzyme reactions etc.
Conductivity	This sensor requires both the adapter and the conductivity electrode 3136. In contrast to the pH electrode this one can be stored dry. There are four ranges: 0 to 100 mS, 0 to 1 mS, 0 to 10 mS and 0 to 100 mS thus permitting work from low ionic concentrations (acid rain) to highly conducting solutions (e.g. sea water). Data harvest recommend that for much work the default calibration would be accurate enough. This was not tested on this occasion.

Environmental Parameter	Comment
Light	Again three models are available but only two are likely to be used in environmental monitoring. The 3122 is an all-purpose light sensor (0 to 100,000 lux) suitable for outdoor use, e.g. in sunlight. A smoothed response is designed to filter out high frequency signals. The response rate was satisfactory. The 3120 (0 to 1,000 lux) has a photodiode sensitive to light in the 350 nm to 700 nm range (i.e. a response similar to that of the human eye). The slow linear response is suitable for studying plant growth indoors for example.
Oxygen	This sensor also requires both the adapter and the oxygen electrode 3131. The oxygen electrode is suitable for use in air (0 to 25% in air) and in saturated solutions (0 to 125% in saturated solution in water). Testing of oxygen content in air gave readings within the expected range but no tests were done to ascertain dissolved oxygen.
pH	pH measurement requires both the adapter and the all-purpose electrode 2251 (Ag / AgCl gel electrolyte). The glass electrode, attached to the end of a plastic body, must be stored wet. It must be rinsed with distilled water or the next test sample between tests as usual. Depending on accuracy needed it can be used without further calibration but is better calibrated with standardised buffer solutions. As with most pH electrodes there is a shelf life even if not much used. Not extensively tested but worked effectively and with reasonable accuracy. For very low conductivity solutions (e.g. acid rain) the electrode 2251 has a glass membrane stored in saturated KCl. Not tested at this time
Relative humidity	This sensor measurement of the water vapour content relative to the ambient temperature (0 to 100% with an accuracy of about 2 to 5% depending on which part of the range is investigated). The narrow end piece was found to be useful in reaching some small and awkward locations. Obviously responsive to damp air the sensor must not be immersed in water.
Sound	The 3175 model covers the 40 to 110 dBA range. The sensor responded rapidly and gave sensible values in all conditions tested. It also measures frequency content in mV. As with most sensors it is not water resistant.
Temperature	Three temperature sensors are produced but only two are likely to be used in environmental monitoring. The 3100 has a range of -30 °C to 110 °C accurate to +/- 0.3 °C, except at the ends of its range, is a general purpose thermometer. Made of stainless steel the thermistor at the end is resistant to weak acids and is generally corrosion resistant. The response was not very rapid but fast enough for most purposes. Water should not be allowed to get into the PVC insulated cable. Model 3101 also has a range -30 °C to 110 °C accurate to +/- 0.3 °C, and is similar to the 3100 but the thermistor is unhoused, allowing it to be used to measure temperature in small locations and confined spaces. (It can also be more easily attached to the body for biological measurements). Likely to corrode if used with chemical solutions.
Ultraviolet	The 3277 model is sensitive to both UVA and UVB radiation. Six ranges are available from 0 to 50 Wm-2 up to 0 to 500 Wm-2. Whilst detailed tests would have been extremely time consuming, the effect of cloud cover on the levels of UV followed expected patterns. There is a wide range of possible investigations relating to effectiveness of sunscreen creams to UV output of, e.g. light bulbs

Costs

Sensor	Supplier	Catalogue number	Cost
Air pressure (& altitude)	Data Harvest	3140	£49.00
	Scientific & Chemical	DAT 060 720	£49.00
Carbon dioxide gas	Data Harvest	3152	£199.00
Colorimeter	Data Harvest	3275	£69.00
	Scientific & Chemical	DAT 060 840	£69.00
Conductivity adapter	Data Harvest	3135	£29.00
	Scientific & Chemical	DAT 060 740	£29.00
Electrode	Data Harvest	3136	£29.00
	Scientific & Chemical	DAT 060 750	£29.00
Light normal	Data Harvest	3120	£26.00
	Scientific & Chemical	DAT 060 540	£26.00
Outdoor use	Data Harvest	3122	£26.00
	Scientific & Chemical	DAT 060 560	£26.00
Oxygen adapter	Data Harvest	3130	£39.00
	Scientific & Chemical	DAT 060 610	£39.00
	Data Harvest	3131	£89.00
electrode	Scientific & Chemical	DAT 060 600	£86.00
pH electrode	Data Harvest	2251	£29.00
	Scientific & Chemical	DAT 060 570	£29.00
electrode low conductivity	Data Harvest	2252	£69.00
	Scientific & Chemical	DAT 060 580	£59.00
	Data Harvest	3125	£34.00
adapter	Scientific & Chemical	DAT 060 590	£34.00
Relative humidity	Data Harvest	3145	£59.00
	Scientific & Chemical	DAT 060 710	£59.00
Sound	Data Harvest	3175	£49.00
	Scientific & Chemical	DAT 060 700	£49.00
Temperature	Data Harvest	3100	£29.00
	Scientific & Chemical	DAT 060 500	£29.00
	Data Harvest	3101	£29.00
	Scientific & Chemical	DAT 060 500	£29.00
Ultra violet	Data Harvest	3277	£59.00
	Scientific & Chemical	DAT 060 910	£59.00

There are a number of other sensors for the logger but they are not relevant to a study of environmental factors but the full range should be taken into account when deciding about which logger and which sensors to buy.

8.2.3 DataHarvest software

Compatibility	Windows XP and VISTA
Licence	Easy Sense Advanced comes with multi-user licence. Further multi-user licences available
Installation and operation	The CD was readily accepted by the computer but recognition of the Easy Sense Q Advanced was not found to be quite so straightforward. Clearer guidance would have been helpful. Opening screen offers a range of icons, Home being the main navigation window. Home offers a good range of new experiment options (Easy log, graph, meter, scope, snapshot, timing etc). The Easy log proved straightforward & gave a line graph auto scaling until stopped manually. As with the stand-alone logger it proved easy to adjust the duration and frequency of readings from sensors connected and to achieve different graphical formats. Other facilities included overlaying several runs, smoothing tools, measurement of gradient and area under the graph curve. Enhancement of presentation of graphs to include headers, table, graph, description, labels etc was also available. The Home icon also offers a number of options (open file, open worksheet, open set-up, set-up remote and retrieve records).

Data Harvest produces a very extensive range of books of experiments and work sheets relating to datalogging in the sciences designed to match ages 9 to 14 and 14 to 18. Each comes with a CD. The older range has been produced to reflect changes to GCSE requirements. Whilst by the very fact of production they appear prescriptive, teachers are able to modify to their own pupils' needs and circumstances.

8.3 DCP LogIT

8.3.1 DCP Log IT Datavision BX (and CX)

Width	195 mm
Height	108 mm
Depth	52 mm at top 25 mm at bottom
Weight	519 g
Memory	20,000 data points per sensor in 50 files
Screen size	59 mm by 41 mm The small but clear screen somewhat limits the amount of information displayed.
Carry case	Comes with a hard carry case

Ports	Top vertical face - power socket, 6 large DIN ports for sensors Left hand vertical face - serial port and USB socket
Battery	Rechargeable NiMH battery. Charging is either from mains or when connected to computer. Charging should ideally be in excess of 24 hours. Batteries should have a life of about a year with normal usage The battery should last up to 8 hours in field use, longer if allowed to 'sleep' in remote logging (though this depends on which sensors are being used).
Wireless connection	It has no wireless facility as standard but a Bluetooth option is available and is plugged in to the serial port.
Manual	Comes with straightforward getting started guide.
Upgrades	Software updates available from the website
Weather proofing	No datalogger is waterproof. In the field users are advised to store in a waterproof cover such as a plastic or other box (or to use the box provided).
'Field' use	The size and weight make it less easy than some loggers to carry round in the field although a carry case helps to resolve this.
Operation	This datalogger can be used a stand-alone device to record, analyse and display data or as an interface to another computer. Installation of the USB driver before charging (from the CD supplied) is easy and quick. Navigation is by a four-base joypad to the left of the screen. The menu is easily navigated by the up and down buttons. Power saving operates – restart from any button. The menu offers continuous logging, individual readings (e.g. at specific events) or snapshot logging. Sensors are easily connected via leads and are recognised by the logger. Several sensors can be tracked at the same time. Six of the toggle keys (buttons) to the right of the screen enable each channel to be displayed separately. The remaining keys access the menu, edit and zoom facilities. Start and stop buttons operate logging that can be tracked by a meter or a graphical display. The snapshot mode allows sensor readings to be captured on demand and now the data is readily stored in the memory. There is a default setting for straightforward logging but the recording period and frequency of readings were easily altered to suit the investigation e.g. for very fast or much slower set of changes. Up to 50 sets of experimental data can be stored in the Datavision memory. Data may be saved to a separate computer using the logIT software.

DCP also produces the logIT CX which is similar to the BX but has additional features including an oscilloscope, frequency counter and logic analyser but for environmental monitoring alone the BX would be adequate.

Costs

Supplier	Catalogue number	Price
Griffin Education Datavision BX, guide and case. The single-user software is extra	CRD-810-010T	£299.00
Griffin Education Datavision CX, guide and case. The single-user software is extra	CRD-800-010D	£359.00
Rapid Datavision BX, guide and case. The single-user software is extra	85-2679	£286.00
Rapid Datavision CX, guide and case. The single-user software is extra	85-2677	£344.00
TAG learning Datavision	Datavision serial or USB	£429.00
Timstar Datavision BX, guide and case. The single-user software is extra	DA61225	£299.00
Timstar Datavision CX, guide and case. The single-user software is extra	DA61223	£359.00

8.3.2 DCP logIT Voyager SX

Width	78 mm at top
Height	165 mm
Depth	41 at deepest 35 mm at shallowest
Weight	238 g
Memory	Will store 4 experiments with 250 readings per sensor in autolog mode but this can be increased using a free firmware update
Screen size	52 mm by 16 mm (small screen limits the amount of data displayed).
Carry case	Comes with a hard carry case

Ports	Top vertical face - 3 large DIN ports for sensors Bottom vertical face - serial socket
Battery	Four AA alkaline batteries. These are easily replaced through back of logger using screwdriver provided. Can also be run from a computer via a USB connection. The battery life in field use depends on which sensors are being used but should be at least 12 months
Wireless connection	The SX has no wireless facility but the SX AIR ONE is Bluetooth enabled.
Manual	This comes with a guide including suggested activities.
Upgrades	Software updates are available from website
Weather proofing	No datalogger is waterproof. Voyager comes in a hard carry-case which offers some protection.
'Field' use	The design with a hand grip and the relatively light weight makes use in the field relatively easy.
Operation	This datalogger can be used a stand-alone device to display investigation results as they happen or as an interface to a computer. Installation of the USB driver from CD supplied before charging is easy and quick. A three-button navigation pad makes manipulation very simple. Power saving operates – restart is from any button. Can be used for continuous logging displaying values usually determined by the sensor inserted. This can also be altered using the '?' button and selecting from the options open for that sensor. An autolog setting enabled readings to be taken both for immediate usage and for remote longer-term work. The frequency of readings was rapid to start with but extended to longer periods when the logger was left for a period of time. The logging rate can also be set via the three keys. Sensors easily connected via leads & were auto-recognised by the logger. The screen, though small, was clear. The saved data can easily be transferred to a separate computer using the logIT software and analysed and presented in required graphical or other format.

DCP also makes the logIT Explorer, which is designed for primary and middle schools and is probably suitable for use up to the end of KS3. It therefore overlaps in use with the Voyager. The size, shape and weight is similar to the Voyager but it has the advantage of built-in light, temperature and sound sensors. There is also a jackplug facility for connecting a different sensor (which could then over-ride the in-built one). However, sensors designed for use with Datavision or the Voyager cannot be used with the Explorer directly. As with the Voyager a USB connection enables data to be transferred to a computer and analysed and displayed.

Costs

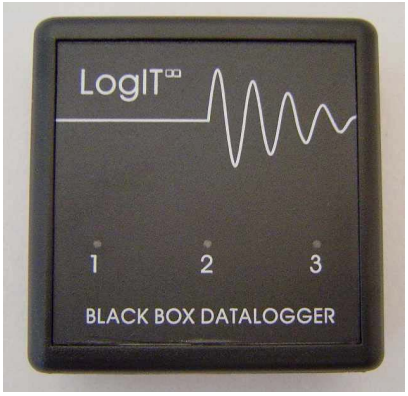
Supplier	Catalogue number	Price
Griffin Education Voyager SX includes logger, temperature sensor (and software, manual etc)	CRD-550-010P	£199.00
Griffin Education Voyager SX Air includes Bluetooth enabled logger, temperature sensor (and software, manual etc)	CRD-550-S	£249.00
Rapid Voyager SX includes logger, temperature sensor (and software, manual etc)	85- 2681	£191.00
TAG Learning Voyager SX	Voyager SX	£199.00
Timstar Voyager SX includes logger, light and temperature sensor (and single-user software, guide etc)	DA61217	£199.00
Timstar Voyager SX Air includes Bluetooth enabled logger, light and temperature sensor (and single-user software, guide etc)	DA61219	£249.00

Voyager comes in both Windows and Mac versions.

Supplier	Catalogue number	Price
Beecroft		
Explorer starter pack	WDA 00101 serial port	£263.26
	WDA 00102 USB port	£253.13
Blackboard Associates		
Explorer including temperature probes	LogIT Explorer serial or USB port	£180.00
Commotion		
Explorer starter set	12452 USB port	£179.00
GLS		
Explorer	G48373270	£200.90
Griffin Education		
Explorer starter pack	CRD-600-030N	£179.99
NES Arnold		
Explorer	04BJ72620	£229.95
Rapid		
Explorer	85-2660 serial port	£163.00
	85-2661 USB port	£173.00
RM		
Explorer	1CZ-900 USB port	£179.99
	1CZ-901 Serial port	£169.99
TAG Learning		
Explorer including 2 temperature probes	Explorer	£169.00
Timstar		
Explorer includes logger, light sensor (and single-user software, guide etc)	DA61238 (serial port) Also available at same price with USB port	£179.99
TTS		
Explorer	849-LogIT	£165.00
YPO		
Explorer	D90350 serial port	£165.00
	D90351 USB	£175.00

Explorer comes in both Windows and Mac versions.

8.3.3 DCP logIT Black Box Interface



Width	66 mm
Height	66 mm
Depth	30
Weight	76 g
Memory	Not relevant
Screen size	It has no screen
Carry case	Comes with a hard carry case

Ports	Top vertical face - USB port Bottom vertical face - 3 large DIN ports for sensors
Battery	No battery required
Wireless connection	Not relevant
Manual	Comes with a guide including suggested activities.
Weather proofing	No datalogger is waterproof.
'Field' use	The Black Box is designed as an interface and because it has no internal power source it can only be used with a computer and not as a stand alone instrument. It is more appropriate for laboratory use since it would need a computer to operate in the field.
Operation	This is simply an interface and must be used to link sensors with a computer. It cannot be used as a stand-alone instrument. Installation of the USB driver from CD supplied before charging is easy and quick. Sensors were easily connected via leads and were auto-recognised by the logger showing by one of three different coloured LEDs. The software enabled control of the sensors from the computer and offered four levels of operation. Secondary pupils are most likely to use the advanced level. The data was automatically transferred to the computer and using the logIT software was analysed and presented in required graphical or other format.

Costs

Supplier	**Catalogue number**	**Price**
Griffin Education Black Box interface	CRD-960-010W	£85.00
Griffin Education Black Box interface with temperature and light sensor, guide and software	CRD-960-020T	£99.00
Timstar Black Box Interface	DA71020	£85.00
Timstar Also available with temperature and light sensor, guide and software	DA71025	£99.95

8.3.4 DCP logIT Microsense sensors

The sensors discussed below can be used with a variety of logIT dataloggers except the Explorer. A more limited range of sensors is available for the Explorer logger since its main use is in lower-school work.

Environmental Parameter	Comment
Air pressure	The DA61253 measures pressure in hPa covering range 800 to 1,100 hPa (i.e. 80 to 110 kPa). On testing results matched to other pressure readings with sufficient accuracy. It can also act as an altimeter with a range of -500 m to 12,000 m. This aspect was not tested.
Carbon dioxide	One of the more expensive sensors the DA671100 uses non-dispersive IR to measure carbon dioxide in ppm with a range of 0 to 2,000 (+/- 3%) ppm. The cell must be kept water free. It can be run by a power supply or via two AA batteries that are easily accessed. The default frequency of readings is 2 per second though this can be adjusted. A fairly heavy power usage is minimised by switching on only when readings are being taken. It proved to be relatively easy to use and to follow readings. The variation in readings seemed appropriate but more detailed testing would be needed to confirm their accuracy.
Colorimeter	The DA61294 includes a cuvette but avoids the need for separate colour filters by use of multicolour LED emitters. It measures absorbance of light through a coloured solution as % (and hence % transmittance). Calibration is via selection of wavelength and calibration to 100% transmittance. It proved to be very sensitive in use though drift was noticeable unless stabilisation time was allowed. It is suitable for, e.g. comparing turbidity in water samples, formation of algae etc.
Conductivity	The DA61270 comes as an adapter and probe set operating up to 20,000 µS. It comes with a long cable simplifying use in water quality investigations. It can be calibrated with a standard solution close to that being tested. The need to allow stabilisation time makes this a slow process. The probe should be washed in distilled water after use and stored wet.
Dissolved Oxygen	The DA61207 probe comes in a set with an amplifier, membranes and KCl solution. It has auto temperature compensation over 5 °C to 45 °C range. The electrode needs care as with the pH electrode. In use the solution must be stirred to avoid oxygen depletion near the probe. Notes also suggest sterilisation for 10 to 20 minutes. It is quite slow and complex to use as with other oxygen probes.
Electrosmog	Electrosmog is name given to man-made RF emissions that may interfere with hospital or aircraft instruments (and some believe health). DA71105 sensor has a built in dipole aerial to detect field strength of RF signals (measured in watts/metre) in the 800 to 2,500 MHz range. Testing in the lab gave a comparative measure of RF signals arising from different equipment such as mobile phones, alarms etc and showed that certain types of shielding are possible.

Environmental Parameter	Comment
Light	Four models are available but not all are likely to be used in environmental monitoring. The SPX LUX (DA61276) covers 0 to 100,000 lux. The silicon photodiode is sensitive to both visible and IR making it suitable for outdoor use, e.g. in sunlight and for measuring light in darker areas such as forest floors. The spectral range is 400 to 1,100 nm. A cheaper general purpose model (DA61271) also covers visible light and IR and measures light levels on a 0 to 100 scale and would be suitable for measuring precipitation rate for example. There is also a slightly more expensive Smarteye model (DA61204) which includes a set of coloured filters that can be used to block IR.
pH	Several (untested) versions are made. Model DA61262 and can be used to link a standard pH electrode to a logIT device. The DA61206 is a pH sensor *and* electrode while the DA61278 has an adjustable sensor. As with almost all pH electrodes, the glass bulb must be stored wet.
Relative humidity	The humipro (DA61267) measures % water vapour content relative to saturated air and responded very quickly. It covers the range 1 to 100% and gave results within the expected range. No water or condensation should be allowed to reach the sensor head. There is also a cheaper general purpose humidity sensor (DA61265) which was not tested but which is slower to respond though may be suitable for checking humidity of different locations / rooms or transpiration of plants etc.
Sound	DA61205 has a range of 50 to 110 dBA (+/- 5). Testing indicated a satisfactory response rate and matched other similar models. As with many sensors it is not designed to be water-resistant but also needs to be sheltered from direct wind gusts. It can also show sound waveform.
Stream flow	The DA61281 has an impeller equipped with a two-piece 1 meter rod and can be held vertically to measure water flow in streams between 5 and 100 cm deep. Though not tested in the field lab tests showed it to be sufficiently sensitive for comparative measurements though the connecting wire at the front of the impeller was awkward to manipulate. Safety precautions are well emphasised.
Temperature	Three temperature sensors are produced (and a K-type thermocouple which is unlikely to be used in environmental monitoring). Hitemp -10 °C to 110 °C (DA61272) is a general-purpose thermometer suitable for air and liquid measurements. It has a small stainless steel tip and on testing responded quickly to rapid temperature change. The waterproof nature, long cable and light weight could be useful in an environmental location. However it is not designed to be resistant to corrosive liquids. Protemp (model DA61203) also -10 °C to 110 °C has a long stainless steel probe and can be used to measure temperature of soft soils as well. There is also a version with a moulded extension lead.
Ultraviolet	This model detects UVA and UVB radiation. Whilst detailed tests would have been extremely time consuming, the effect of cloud cover on the levels of UV followed expected patterns. There is a wide range of possible investigations relating to effectiveness of sunscreen creams to UV output of, e.g. light bulbs.

Costs of Microsense sensors

Sensor	Supplier	Catalogue number	Cost
Air pressure (& altitude)	Timstar	DA61253	£69.90
	Beecroft	WDA 03801	£75.71
	Griffin Education	CRD-220-655X	£69.90
Carbon dioxide gas	Timstar	DA71100	£199.00
	Griffin Education	CRD130-730E	£198.00
Colorimeter	Timstar	DA61294	£79.00
Conductivity adapter including electrode	Timstar	DA61270	£158.00
	Griffin Education	CRD220-680P	£158.00
Dissolved Oxygen adapter and electrode	Timstar	DA61207	£169.00
	Griffin Education	CRD220-670S	£169.00
Electrosmog	Timstar	DA71105	£59.95
	Griffin Education	CRD130-740B	£62.90
Light (normal and outdoor use)	Timstar	SPX LUX DA61276	£29.90
		General DA61271	£15.90
	Beecroft	General WDA 02501	£17.31
		Lux WDA 02601	£64.70
	Commotion	12201	£8.00
	Griffin Education	General CRD130-512X	£15.90
		LUX CRD130-625B	£59.90
		SPX LUX CRD130-627U	£29.90
pH amplifier and electrode	Timstar	DA61206	£79.90
	Timstar adapter	DA61282	£6.00
	Beecroft	WDA02801	£92.43
		WDA02802	£43.26
	Commotion (electrode only)	12215	£40.00
	Griffin Education	CRDF130-554V	£79.90
	Rapid	85-2618	£77.20
	RM	QJM-918	£66.49
Relative humidity	Timstar	Humipro DA61267	£98.00
		General DA61265	£75.00
	Beecroft	WDA 03301	£81.08
	Griffin Education	General CRD130-630Y	£75.00
		Humipro CRD220-645R	£98.00
Sound	Timstar	DA61205	£39.90
	Beecroft	WDA 03201	£43.26
	Commotion	12080	£40.00
	Griffin Education	CRD130-585K	£39.90
	Rapid	85-2612	£38.55

Sensor	Supplier	Catalogue number	Cost
Stream flow	Timstar	DA61281	£149.90
	Beecroft	WDA 03401	£162.24
	Griffin Education	CRD130-750V	£149.90
Temperature	Timstar	Protemp DA61203	£24.80
		Hitemp DA61272	£15.90
	Beecroft	Protemp WDA 02201	£27.04
	Commotion	Protemp 12073	£15.00
		Hitemp 12071	£16.00
	Griffin Education	Protemp CRD130-570A	£24.90
		Hitemp CRD130-506J	£15.90
	Rapid	Protemp 85-2608	£24.10
		Hitemp 85-2606	£15.35
Ultra violet	Timstar	DA61285	£95.00
	Griffin Education	CRD130-755L	£95.00
	Rapid	85-2685	£92.00

There are a number of other sensors for the logger but they are not relevant to a study of environmental factors but the full range should be taken into account when deciding about which logger and which sensors to buy. Several companies sell sensor packs, which may be worth investigating if a school is looking to purchase a range of sensors at one time.

Costs of Explorer sensors

Sensor	Supplier	Catalogue number	Cost
pH	Beecroft	WDA 00305	£85.45
	Commotion	12461	£70.00
	Griffin Education	CRD-650-020E	£69.99
	NES Arnold	04BJ72623	£119.95
Temperature	Beecroft	WDA 00304	£21.63
	Commotion	12460	£19.99
	Griffin Education	CRD-650-010H	£20.00
	NES Arnold	04BJ72625	£49.95

8.3.5 DCP LogIT Lab 4 software

Compatibility	Compatible with Windows 95, 98, NT, XP and is VISTA compliant.
Licence	LogIT comes with single-user licence but multi-user Site licences are available. However it should be noted that each different logger model has a different licence.
Installation and operation	The CD was readily accepted by the computer and recognition of the LogIT was quite straightforward. The opening screen offers a range of 4 levels of sophistication, the Advanced being the most appropriate for secondary working. The software autodetects sensors linked to the logger and as with the stand alone logger there is a choice of autolog or manual adjustment and as before it proved easy to adjust the duration and frequency of readings from sensor(s) connected. There was a choice of snapshot or continuous readings. Control of investigations was as straightforward as with the stand-alone logger. The advanced setting of LogIT Lab offers a choice of presentation styles including real-time graphs, bar variation charts, digital display or tabulated results. It is also possible to have all four displayed at once using a split screen system. This has some advantages but tended to make the screen appear over-busy. Data manipulation facilities included overlaying several runs, graph zooms, best fit, data smoothing, measurement of gradient and area under the graph(s) curve, differentiation and integration. Enhancement of presentation of graphs to include headers, table, graph, description, labels etc was also available and easy to use. It proved easy to print to a standard printer. It proved easy to fetch data from previous runs that had been captured in a logger and then to adjust the format and presentation of this data. Data may be copied to Excel or Inspire and the system is compatible with Insight systems.

There is a booklet of suggested experiments, some of which have an environmental theme. These are not very prescriptive and could be used as a starting point for teachers to modify and adapt to their own pupils' needs and circumstances.

8.4 Vernier Labquest

8.4.1 Vernier Labquest

Width	103 mm at top 78 mm at bottom
Height	165 mm
Depth	37 mm at top 18 mm at bottom
Weight	354 g
Memory	40 Mb (can be extended via a SD / MMC card or USB stick).
Screen size	74 mm by 55 mm
Carry case	No carry case is available yet

Ports	Top vertical face – 4 sensor ports and USBs for Windows & Mac and printer Left hand vertical face – audio in / out and power jack sockets Right hand vertical face – 2 sensor ports Built-in microphone
Battery	Rechargeable lithium ion battery pack. Charging is either from the mains or when connected to computer. The battery should last at least a day in field use (though this depends on which sensors are being used).
Wireless connection	No wireless facility yet but Vernier is working on Bluetooth capability.
Licence	No licence is needed for Labquest.
Manual	This comes with a ‘Quick-start’ guide giving clear instructions on using the Labquest as a stand-alone device or linked to a computer.
Upgrades	Software can be upgraded on line from Vernier or IDS website.
Weather proofing	The Labquest is shock resistant and shower-proof but not to full immersion. In the field users are still advised to store in a waterproof cover such as a plastic box.
‘Field’ use	The small size and modest weight make this relatively easy to use in the field.

Operation	This neat datalogger can be used a stand-alone device to record, analyse and display data or as an interface to another computer. Installation of the USB driver from CD supplied before charging is easy and quick. There is a built in temperature sensor giving ambient temperature readings and a built in microphone and sound sensor. Access is by a start button and navigation The screen dims if not used but though there is no short-term power saving this will kick in if Labquest has not been used for some time. Sensors are easily connected via leads and are instantly recognised by the logger. Several sensors can be tracked at the same time. The remaining keys access the menu, edit and zoom facilities. The touch-screen is operated by a stylus and gave a rapid response. The menu offers continuous logging, individual readings (e.g. at specific events) or snapshot logging. The start button operates logging that can be tracked by a meter or a graphical display on the good-sized screen. The graph autoscaled where necessary to accommodate the data collected. Several runs may be collected and displayed together if required. Snapshot mode allows sensor readings to be captured on demand and now the data is readily stored in the memory. There is a default setting for straightforward logging but the recording period and frequency of readings were easily altered to suit the investigation e.g. for very fast or much slower set of changes. Up to 50 sets of experimental data can be stored in the memory. Data may be tabulated, analysed and displayed. It proved straightforward to modify the table of data and to add notes on activities via an on-screen keyboard. There is also a facility to add pictures. The menu also offered a stopwatch facility, a scientific calculator, a range of experiments and access to a periodic table display. As an alternative the data was saved to a separate computer using the Logger Lite or Logger Pro software and analysed there. The Labquest software is Linux- based but is compatible with Logger Lite. It is possible to connect Labquest direct to a printer without linking to a separate computer. Vernier also produces a series of books of experiment suggestions relevant to different aspects of science. Each book comes with a CD version. Whilst these are written for the American market, many of the ideas could be adapted for local curriculum needs.

Costs

Supplier	Catalogue number	Price
Granet (South of England) IDS (North of England) Vernier Labquest (Includes Logger Lite software and temperature probe)	LQ-QSP	£319.00

8.4.2 Vernier Sensors

Environmental Parameter	Comment
Barometer (air pressure)	The BAR-BTA has a range 81 to 106 kPa (25 to 31.5 in mercury). It is suitable for studies where air pressures are within the usual range. It gave a clear, accurate and suitably fast response.
Carbon dioxide	This measures gaseous carbon dioxide levels within two ranges: 0 to 10,000 ppm and 0 to 100,000 ppm. The lower range is probably more useful and more sensitive. The sensor package includes a 250 ml gas sampling bottle. Monitoring carbon dioxide variation in an occupied room gave sensible results though response was slow.
Colorimeter	This four-wavelength colorimeter was not tested but would be useful e.g. in determining concentrations of unknown solutions. It includes a supply of cuvettes. Wavelengths covered are 430 nm, 470 nm, 565 nm and 635 nm. It has automatic one button calibration.
Conductivity	The conductivity probe can be used for testing total dissolved solids or such things as salinity in water samples. Although not tested it has three different sensitivity settings and automatic temperature compensation over 5 °C to 35 °C.
Dissolved Oxygen	This sensor has a range of 0 to 14 mg/l dissolved oxygen but was not tested. It has built in temperature compensation over the range 0 °C to 35 °C. It requires the usual care with storage and maintenance.
Light	A single silicon diode unit covers three ranges that can be selected via a switch. 0 to 600 lux, 0 to 6,000 lux and 0 to 150,000 lux. The spectral range is similar to that of the human eye. The lowest range proved to be the most sensitive but the range chosen will depend on the investigation.
pH	The sensor is the usual Ag-AgCl combination electrode with storage bottle and solution. Unless very high accuracy is required it is not necessary to recalibrate. As with all pH electrodes maintenance and proper storage are essential and even then the electrodes have a limited life.
Relative humidity	The range is 0 to 95% (accuracy +/- 5%). Unless very high accuracy required, calibration proved unnecessary. Calibration is also affected at higher temperatures and highish humidities. Response time was slow in still air but faster in moving air stream, e.g. encouraged by a gentle fan.
Soil moisture	This operates over 0 to about 45% moisture level by volume. It should be used vertically to avoid making contact with a pool of water on or in the soil. More accurate results are obtained if the soil is compacted to give good contact. Investigation can clarify whether soil moisture content varies with depth. No further calibration is required unless very high accuracy required. Care was needed in removal from the soil to avoid damaging prong / plates.
Sound	This operates over a slightly wider range than many sound level meters covering 35 to 130 dB with an accuracy of 1 to 2 dB. It also has a LCD panel enabling it to be used as a stand-alone meter and a facility to switch between dBA and dBC weighting if this is required. The high cost relative to other sound level devices reflects these wider options which may not be needed by many schools.
Stream flow	As with other stream flow sensors the impeller comes with a four-part rod for easier carriage and a 5 metre cable thus enabling the logger to be kept on the bank. This sensor was not tested but has a range of 0 to 3.5 m/s.

Environmental Parameter	Comment
Temperature	The basic TMP-BTA model has a wider range than many such temperature probes covering -40 °C to 135 °C. It has a stainless shaft and tip, resistant to acids, alkalis and salt solutions. The resolution is 0.1 °C over the most common range. It gave a reasonably rapid response. A similar version (TPL-BTA) comes with a very long cable for remote measurements including temperature measurements below water in streams and lakes. Vernier also produces an exposed thermistor sensor that gives a very rapid response for measurements, e.g. for flexible situations or on skin. It can be used only in air.
Ultraviolet	Separate sensors are used to detect UVA (320 to 390 nm) and UVB (290 to 320 nm). Choice would depend on investigations to be conducted but probably UVB mainly associated with skin cancers and sunburn is more likely to be used. Strictly calibration against radiation of known intensity and spectral distribution is needed (probably pointing at the sun and setting at 100% is accurate enough).

Costs

Sensor	Supplier	Catalogue number	Cost
Barometer (air pressure)	IDS / Granet	BAR-BTA	£64.00
Carbon dioxide gas	IDS / Granet	CO2-BTA	£231.00
Colorimeter	IDS / Granet	COL-BTA	£106.00
Conductivity adapter including electrode	IDS / Granet	CON-BTA	£86.00
Dissolved oxygen probe	IDS / Granet	DO-BTA	£190.00
Light sensor	IDS / Granet	LS-BTA	£49.00
Oxygen gas sensor	IDS / Granet	O2-BTA	£174.00
pH sensor	IDS / Granet	PH-BTA	£73.00
Relative humidity	IDS / Granet	RH-BTA	£64.00
Soil moisture	IDS / Granet	SMS-BTA	£84.00
Sound	IDS / Granet	SLM-BTA	£153.00
Stream flow rate sensor	IDS / Granet	FLO-BTA	£120.00
Temperature	IDS / Granet	TMP-BTA TPL-BTA	£27.00 £65.00
Ultra violet	IDS / Granet	UVA-BTA UVB-BTA	£96.00 £97.00

There are a number of other sensors for the logger but they are not relevant to a study of environmental factors but the full range should be taken into account when deciding about which logger and which sensors to buy.

8.4.3 Vernier Logger Pro and Logger Lite software

Compatibility	The software is compatible with Windows XP and subsequent packages including VISTA.
Licence	Logger Pro comes with a full site licence.
Installation and operation	The CD was readily accepted by the computer and Labquest was readily recognised. The opening screen offers a range of icons parallel to those on the Labquest. As before the sensors were instantly recognised on screen. The menu offered the same range of continuous logging, individual readings (e.g. at specific events) or snapshot logging. The start icon operated logging which was tracked by a meter or by a graphical display on screen. The graph autoscaled to accommodate the data collected. Several runs were collected and displayed together. Snapshot mode allowed sensor readings to be captured on demand and the data was readily stored. As before there is a default setting for straightforward logging but the recording period and frequency of readings were easily altered to suit the investigation. Data was tabulated, analysed and displayed. Zoom (in and out), graph analysis including tangent drawing, integration to obtain areas under graph lines etc were all options. As before there were facilities to modify the table of data and to add notes on activities and to add pictures. Overall this package proved straightforward to use.

8.5 Pasco

8.5.1 Pasco Xplorer GLX (Feedback Instruments)

Width	100 mm at widest
Height	228 mm
Depth	50 mm including feet
Weight	528 g
Memory	12 MB of data storage which can be enhanced using a flash drive (memory stick)
Screen size	78 mm by 60 mm This is large enough to give a clear visual display.
Carry case	A field bag or solid carry case is available to hold the Xplorer, portable keyboard, mouse, small probes etc

Ports	Top vertical face – 4 DIN sensor ports. Right hand vertical face - 2 USB ports (one to connect to a mouse, mobile keyboard, printer or flash drive, etc, and one to link to PC, etc) and power jack point. Left hand vertical face - has 2 built-in temperature probes, voltage port and signal output port. There is also a built-in sound sensor and a speaker for sound output at the bottom of the top face.
Battery	Rechargeable NiMH battery (from the mains) or it can be run from a computer when connected. Initial charging takes about 14 hours. The battery should last about 4 to 5 hours in field use (though this depends on which sensors are being used). Pasco advises GLX should be stored with fully charged battery that typically has a three-year life.
Wireless connection	ML does not have wireless facility but GL does as an optional extra. PASCO has a Bluetooth USB adapter enabling any computer with USB connections and at least Microsoft XP or Mac OS X to become Bluetooth enabled. It also sells a PASPORT Airlink SI to permit any sensor to connect wirelessly to an enabled computer up to the usual limit of 10 m.
Stand	The back of the GLX has a fold-down prop.
Manual	This comes with ‘Quick-start’ instruction cards that have concise instructions and clear illustrations, and a Users’ guide and a DVD-ROM. The Users’ guide is very extensive and gives thorough instructions on using the Xplorer as a stand-alone device or linked to a computer. It also gives sample activities from across the curriculum. The use of pictorial symbols makes the guidance easier to follow but time needs to be allocated to work through the guidance.
Languages	Xplorer supports a range of languages.
Upgrades	Firmware and software upgrades can be obtained on line by registering after purchase.
Weather proofing	The Xplorer GLX is water-resistant but not waterproof. In the field users are advised to store in a waterproof carry case.
‘Field’ use	The design enables hand grip use in the field though this is not the smallest or lightest logger available.

Operation	This datalogger can be used a stand-alone device to record and display data or as an interface to another computer. The top of the machine has four function buttons a five-button keypad and an alphanumeric pad similar to that on a mobile phone. The size of the screen is a distinct advantage by increasing visibility of experimental results. Access is by an on / off button and the home screen always returns using the 'house' symbol on the keypad. The twelve-option screen this displays is readily navigated through the arrow keys. The F1 to F4 buttons are short cuts to graphs, tables, a calculator and sensors. If GLX is running just on the battery it will automatically save data and shut down after 5 minutes idling time. If it is running on mains power and the battery is fully charged it will shut down after 60 minutes of idling time. GLX will also 'sleep' between samples if they are every 30 seconds or slower. Sensors are easily connected via leads and the DIN plugs and are instantly auto-recognised by the logger. The start arrow commences continuous data collection from all connected sensors as default. A manual sampling option at preferred time intervals and a triggered graphical start are options that may be set. The home screen is the central feature of the GLX with 12 main icons and a top and lower bar. These are readily navigated by the arrow keypad (or a mouse if one is connected). All sensors connected are located on the sensors screen and the frequency of data sample collection altered for continuous logging. Each sensor can be adjusted individually. The frequency of manual sampling is determined by the operator, options ranging from 200 per second to one per 4 hours. It is also possible to either display the data collected from a given sensor on the screen or hide it. Data display can be graphical, tabulated or meter. Up to two graph lines can be displayed at a time using black and grey to distinguish and with a y-axis at each side of the graph. Saving of data is straightforward. Analysis tools then include graph-smoothing, autoscaling, zoom selection of graph sections, gradients, differences, area, linear fit etc. It also proved straightforward to modify the table of data and to add notes on activities via the keyboard. Data may also be tabulated, analysed and graphically displayed after transfer to a PC using the Datastudio software. The extensive calculator functions are accessible from the keypad and include basic mathematical calculations, algebraic calculations and graphical ones as well as the sensor based ones. A comprehensive GLX Users' guide was provided. This proved to be clear and reasonably easy to understand. A tutorial CD Users' guide to stand alone datalogger activities for the GLX was also available but the sound level was too low for easy use. Otherwise it proved to be a helpful support to the layout of the GLX and to its range of facilities.

Pasco also makes the simpler, smaller and cheaper Xplorer datalogger. Inevitably this has fewer functions and is more limited in its capability but may be worth consideration for certain circumstances.

Costs

Supplier	Catalogue number	Price
Feedback Instruments Xplorer GLX (including Datastudio Lite software and 2 stainless steel temperature probes)	PS-2002	£283.00

8.5.2 Pasport Sensors

Connection of the neat sensors in each case is via a small DIN plug. Pasco produces a larger number of multiple parameter sensors than most suppliers, e.g. temperature / sound / light.

Environmental Parameter	Comment
Air pressure (barometer)	The PS2113A has ranges of 150 to 1090 mbar and 15 to 109 hPa and is quite sensitive enabling for example changes in air pressure from floor to ceiling in a room.
Carbon dioxide	The PS2110 is quite expensive. It comes with a probe and 250 ml sampling bottle and bung. It has a range of 0 to 300,000 ppm with an accuracy of about 10%, thus offering a wide range of uses. Further calibration should not be required but over time may prove necessary and clear directions are given. Use is straightforward but time was needed for the sensor to warm up even at room temperature.
Colorimeter	The PS2121 colorimeter was not tested. It has the usual range of 0 to 100% transmittance and 0 to 3 absorbance and reports both simultaneously. Autocalibration is readily achieved with a cuvette of clear water. Wavelengths covered are 660 nm, 610 nm, 565 nm and 468 nm giving a good spectral range.
Conductivity	PS2116A comes with a sensor box and conductivity probe. It has three ranges 0 to 1,000 µS / cm, 0 to 10,000 µS / cm and 0 to 100,000 µS / cm (accuracy improves from about 10% reading to 0.1% after calibration). The glass bulb is well protected within the probe. Instructions for calibration are given but a standard solution of known conductivity is required. This is useful to compare the conductivity of different water samples. Spare probes are available.
Humidity	The PS2124 was not tested but is designed to measure relative and absolute humidity (0 to 100% +/-2%), dew point (-50 °C to 50 °C +/- 0.5%) and temperature (-20 °C to 55 °C +/- 2 °C).
Light	The PS2106A is a very flexible sensor with three different ranges 0 to 2.6 lux, 0 to 260 lux and 0 to 26,000 lux enabling it to be used a in a wide variety of situations. The sensor automatically indicated when a different range is more appropriate. The response to changes in light intensity was rapid. There are other sensors which include light as part of a multiple parameter device such as PS2140 (temperature / sound / light) and the PS2168 general science sensor (temperature / light / sound / voltage).
Oxygen dissolved includes sensor and probe	The PS2108 was not tested. It is quite expensive. The range of 0 to 20 mg/l (accuracy +/- 0.2 mg/l) allows quite small changes in dissolved oxygen content to be measured. The membrane comes in a cartridge and a spare membrane is provided.
Oxygen gas	PS2126 measures oxygen gas concentration in ppm over a wide range (0 to 100% +/- 1%) enabling it to be used for a variety of purposes from oxygen content in air samples to air quality to respiration experiments and breakdown of hydrogen peroxide. Calibration should be not necessary though for very accurate work instructions are given as to how this could be done. The pack comes with a sampling bottle and a sensing element.

Environmental Parameter	Comment
pH	PS2102 includes both sensor box and pH probe, having the typical range of 0 to 14 (resolution 0.01 pH). The usual issues arising from storage, care and maintenance of the probe apply and calibration against known pH buffer solutions is essential unless tests are purely qualitative. pH may also be measured using PS2147 the pH / temperature / ISE / ORE sensor.
Sound	PS2109 is also flexible having three overlapping sound level ranges 30 to 70 dB, 50 to 90 dB and 70 to 110 dB, with an accuracy of about +/- 2 dB. Although not tested it has the flexibility to measure both sound level (measured in dB) and sound intensity (measured in micro Watts per sq m). The screen display shows both dBA (matching human ear sensitivity) and dBC (equal response to all frequencies). Sound is also measured in other sensors as part of a multiple parameter device such as PS2140 (temperature / sound / light) and the PS2168 general science sensor (temperature / light / sound / voltage).
Stream flow rate	The PS2130 was not tested. It consists of an encased impeller with the usual range of 0 to 3.5 m/s. The telescopic handle extends to 6 feet giving a good range to reach into deeper water safely. A built in thermometer indicates temperature at the depth of flow rate measurement.
Temperature	The range of thermometers includes the PS2125, which has a stainless steel probe that is reasonably resistant to attack from many solutions. The range of -35 °C to 135 °C (accuracy +/-0.5 °C) is wider than most similar devices and the response is rapid. There is a wide range of temperature-measuring devices for specialist situations (e.g. skin surface) and as part of a multiple parameter sensor such as PS2140 (temperature / sound / light) and PS2147 (pH / temperature / ORP / ISE) and the PS2168 general science sensor (temperature/ light / sound / voltage).
Thermocline	Although not tested the PS2151 offers the ability to measure temperature as a function of water depth with an extensive depth range of 0 to 10.5m and a temperature sensor over the range 0 °C to 100 °C. A weighted cable is designed to give more reliable depth measure. The cost may encourage schools to opt for a simpler way of investigating the relationship between depth and temperature.
Ultraviolet	The PS2149 was not tested but measures UVA band radiation (and extends into the visible range) using a photodiode sensing element, a filter and collimator.

Costs

Sensor	Supplier	Catalogue number	Cost
Barometer (air pressure)	Feedback	PS-2113A	£80.00
Carbon dioxide gas	Feedback	PS-2110	£224.00
Colorimeter	Feedback	PS-2121	£107.00
Conductivity adapter including electrode	Feedback	PS-2116A	£89.00
General science	Feedback	PS-2168	£134.00
Humidity	Feedback	PS-2124	£71.00
Light sensor	Feedback	PS-2106A	£53.00
Oxygen / dissolved oxygen adapter and electrode	Feedback	PS-2108	£197.00
Oxygen gas	Feedback	PS-2126	£170.00
pH / temperature / ISE / ORP	Feedback	PS-2147	£104.00
pH sensor and electrode	Feedback	PS-2102	£71.00
Sound	Feedback	PS-2109	£89.00
Stream flow rate	Feedback	PS-2130	£116.00
Temperature	Feedback	PS-2125	£26.00
Temperature / sound / light	Feedback	PS-2140	£80.00
Thermocline	Feedback	PS-2151	£233.00
Ultraviolet	Feedback	PS-2149	£143.00

Pasco offers an extremely wide range of sensors. This range includes a number which would be useful for other aspects of environmentally related work than those detailed above including several water quality sensors, a weather sensor, which measures a range of parameters in one instrument and a turbidity sensor. As with a few other companies, PASCO also produces a GPS position sensor that enables investigations of one parameter to be directly related to the location, both sensors being plugged in to the Xplorer GLX simultaneously. Some of these sensors are expensive but this full range should be taken into account when deciding about which logger and which sensors to buy.

8.5.3 Pasco Datastudio software

Compatibility	Compatible with Windows 98, ME, 2000, XP and VISTA and Mac OSX.
Licence	Licences can be single user or site; the latter being more expensive but the Lite version of the software is available from the web site free of charge.
Installation and operation	The installation CD loaded easily on to a PC. It made rapid and easy connection to the GLX and transfer of data from the logger to the PC was straightforward. Downloaded data could be analysed as easily as on the GLX direct and equally environmental investigations could be controlled from the PC. The CD included an interactive tutorial on which the sound level was very low, making it difficult to hear. The insertion of applause at response points proved irritating. The menu offered the same range of facilities as on the GLX. As before the sensors were instantly recognised on screen. The menu offered the same range of continuous logging or individual readings (e.g. at specific times). Navigation around the options proved straightforward. As before the frequency of data sample collection could be altered to suit for continuous logging. The frequency of manual sampling is still determined by the operator with the same range of options. Data display as before could be graphical, tabulated or meter. Up to two graph lines could be displayed at a time with a y-axis at each side of the graph. Saving of data is straightforward. Analysis tools are the same including graph smoothing, autoscaling, zoom selection of graph sections, gradients, differences, area, linear fit etc. It also proved straightforward to modify the table of data and to add notes on activities via the keyboard. The extensive calculator functions are still accessible as before. Overall this software proved straightforward to use once installed.

8.6 Sciencescope

8.6.1 Sciencescope Logbook ML

Width	124 mm at widest
Height	115 mm
Depth	40 mm including feet
Weight	257 g
Memory	Logbook ML has 8 files with up to 48 days recording on each.
Screen size	58 mm by 13 mm on ML (The GL has a larger screen with graphical display which is more easily seen)
Carry case	A carry case is available.

Ports	Top vertical face – power jack point and USB to connect to a computer. Bottom vertical face – 2 sensor ports (GL has 4), min-jack socket is for the ML temperature probe and in-built temperature, light and sound sensors.
Battery	9 V PP3 battery or can be operated from the mains. (GL has a rechargeable NiMH battery and can be charged from the mains or from computer when connected). ML battery operation should give up to 200 recordings. The GL should last at least a day with Bluetooth on in field use (though this depends on which sensors are being used).
Wireless connection	ML does not have wireless facility but GL does as an optional extra.
Manual	It comes with a teacher's guide giving clear and relatively concise instructions on using the Logbook ML (or GL) as a stand alone device or linked to a computer and the software.
Upgrades	Software can be updated from the Sciencescope website.
Weather proofing	The Logbook ML is shower-proof but not waterproof. In the field users are advised to store in a waterproof carry case.
'Field' use	The modest weight and size make this logger easy to use in the field.
Operation	This neat datalogger can be used a stand-alone device to record and display data or as an interface to another computer. There is a built in temperature sensor (0 °C to 45 °C) which can be overridden by the plug in thermometer, a light sensor (0 to 110,000 lux) and a sound sensor (50 to 110dB). Access is by an on/off button and navigation is through two further user buttons, also below the screen, that proved easy to follow. (The GL has extra buttons). Power saving operates after two minutes though the interval is longer in meter screen or snapshot mode. Restart is from any button.

Operation (continued)	Sensors are easily connected via leads and are instantly recognised by the logger. Sciencescope sensors or Philip Harris SensorMeters or Firstsense sensors can be used. Several parameters can be tracked at the same time. The menu offers continuous autologging, triggered logging, fast recording or snapshot logging. The start button operates logging that can be tracked by a meter on a LCD display on screen. Up to four channels of sensor values may be displayed at once. Snapshot mode allows sensor readings to be captured on demand and now the data is readily stored in the memory files. For normal remote logging operations the maximum sample rate is 8 per second and logging will continue for over 40 days unless stopped. In snapshot remote mode readings can be taken at any time. Display on the ML shows values on screen in SI units. Display on the GL can be graphical and meter display. Data may be tabulated, analysed and graphically displayed after transfer to a PC using the Multilab software. Analysis tools then include graphing, gradients, differences, area etc. It proved straightforward to modify the table of data and to add notes on activities via the keyboard.

Sciencescope also makes other versions of the Logbook logger. These include the GL (which has an option of Bluetooth wireless connection), SE and XD. The UL and WL models have essentially been replaced by the GL. There is also a Logbook Primary model. The UL and WL had no in-built sensors but had four sensor ports. The XD has four sensor ports and a small screen while the SE has temperature and light internal sensors and two sensor ports but no display screen.

Costs

Supplier	**Catalogue number**	**Price**
Sciencescope		
Logbook GL	S1313	£200.00
Logbook GL wireless	S1314	£250.00
Logbook ML USB	S1315	£150.00
Wireless adapter	S1796	£45.00

8.6.2 Sciencescope Sensors

Probes come in neat cylindrical plastic containers.

Environmental Parameter	Comment
Air pressure (barometer)	The S1679 can be used to measure air pressure from 830 to 1150 mbar (with a resolution of 0.5 mbar) and can be used at normal altitudes. This model was not tested.
Carbon dioxide	The S1853 was not tested but is designed to measure carbon dioxide levels in the range 0 to 100,000 ppm (resolution 1.5%). The detector cell life is about two years and replacement cells are available.
Conductivity	The S1896 consists of a base unit and probe and has a range of 0 to 100,000 µS (resolution +/- 1.5%). The probe comes dry though long term storage should be in deionised water in a protective bottle. Calibration as with most conductivity sensors is quite a lengthy process using standard KCl solution. Tests on water samples gave sensible conductivity values.
Electrosmog	The S1850 was not tested but is used to detect broadband electromagnetic radiations and covers the range 0.1 to 70 V/m (with a resolution of 1%). There is also an advanced model (S1851), which is more sensitive to lower emission levels.
Light	The advanced S1862 operated over the range almost 0 to 100,000 lux (resolution 2%). It has a fast and a slow auto-response enabling measurements to be taken at low and high light levels, including full sun. The response rate was satisfactory. For many school activities the cheaper S1074 can be used to measure a wide range of light levels giving readings in log lux (resolution 5%). Accuracy is clearly not as great.
Nitrogen dioxide	The S1695 is a neat self-contained sensor designed to detect nitrogen dioxide in the range 0 to 10 ppm (resolution 0.1 ppm). Tests were carried out comparing levels in parkland and near a busy road and sensible readings were obtained to show the differences.
Oxygen dissolved	The S1899 has an integrated oxygen probe and the built-in electronics provides temperature compensation over a range of 0°C to 50°C. The range is 0 to 20 mg/dm^3 of dissolved oxygen. It was not tested.
Oxygen gas	The S1770 has a range of 0 to 30% (resolution 0.1%). The oxygen cell itself should last for at least a year and a replacement cell can be purchased. It was not tested.
pH	The basic probe S1865 covers the pH range of 0 to 14 and can be calibrated with Datadisc. This model comes with an attached pH probe but the storage and maintenance regime remains as important as ever. Extensive guidance on this aspect is provided and the KCl storage solution is included. Response rate and accuracy were satisfactory.
Relative humidity	The S1867 has a range of 0 to 100% and has built in temperature compensation. It was not tested.
Sound	The S1843 has a range of 30 to 110 dB (resolution 1dB) which covers all normal environments. There is a choice of measurement in sound level (dB) or sound pressure (KPa). The response rate was quite good on comparing a quiet lab with overhead aircraft noise. A more advance probe S1802 is also available enabling remote 1 or 2 point calibration to be carried out.

Environmental Parameter	Comment
Stream flow	The S1699 has a stream flow rate range of 0 to 5 m/sec (resolution of 0.05 m/sec). The impeller is supported on pole held by a handle across which the connecting cable runs. The sensor was not tested.
Temperature	The basic S1698 has a range of -20 °C to 120 °C (resolution 0.2 °C) and can be used for temperature measurements of air or liquids. The metal probe is resistant to corrosion in most mild laboratory chemical solutions. Response time was satisfactory. There is also a skin temperature sensor S1697.
Ultraviolet	The S1869 measures both UVA and UVB radiation within the range 0 to 100 W/m^2 (resolution 1%). Response to external investigation of the effect of clouds on UV radiation from the sun gave a suitably fast and appropriate response.

Costs

Sensor	Supplier	Catalogue number	Cost
Barometer (air pressure)	Sciencescope	S2005	£85.00
Carbon dioxide gas	Sciencescope	S1853	£100.00
Conductivity incorporating probe	Sciencescope	S2004	£120.00
Electrosmog basic	Sciencescope	S1850	£35.00
Light sensor general advanced	Sciencescope	S1074 S1862	£20.00 £45.00
Nitrogen dioxide	Sciencescope	S1695	£150.00
Oxygen dissolved	Sciencescope	S1899	£150.00
Oxygen gas	Sciencescope	S1770	£120.00
p probe	Sciencescope	S1865	£60.00
Relative humidity	Sciencescope	S1867	£45.00
Sound	Sciencescope	S1843	£30.00
Stream flow rate	Sciencescope	S1699	£200.00
Temperature	Sciencescope	S1698	£20.00
Ultra violet	Sciencescope	S1869	£65.00

There are a number of other sensors for the logger including a range of relatively costly ion-selective sensors suitable for water quality measurements and air pollution gases such as sulfur dioxide and carbon monoxide, but many of the others are not relevant to a study of environmental factors. Nevertheless, the full range should be taken into account when deciding about which logger and which sensors to buy. Sciencescope also produces a colorimeter, looking like a version of the Logbook, which can be used as a stand-alone device or connected to a datalogger. (S1647).

Sciencescope has also introduced a Garmin etrex location monitoring device (S1312) which combines a GPS unit with a Logbook to generate Google Earth based visualisations of data from any Sciencescope sensor. This enables a visual display showing a pictorial map of an area or journey with the level of say carbon monoxide or dioxide at different points.

8.6.3 Sciencescope Datadisc Pt software

Compatibility	Compatible with Windows XP and VISTA though will probably work with 98, ME and 2000. Will also work with UNIX and Windows mobile.
Licence	Sciencescope will negotiate a licence with the school.
Installation and operation	Datadisc was readily accepted by the PC and automatically created a screen icon. Logbook ML was then readily recognised when connected to the PC. Datadisc offers three levels for working (including one suitable for KS2 that has animated characters). The menu offered the same range of normal (continuous logging) and snapshot logging (On the GL 'roll capture' which enables up to 12 seconds of data to be saved within a 2 minute window, scroll graphed and stopped and saved on screen is also available). The start icon operated logging which was tracked by a meter, tabulated results or a graphical display on screen. The graph autoscaled to accommodate the data collected. Up to three parameters could be tracked on the same graph simultaneously though some pupils might find having two of the scales appearing to the right of the graph slightly confusing despite the use of three colours. Collected data was readily saved. As before there is a default setting for straightforward logging but the recording duration, frequency of readings and number of points displayed were easily altered to suit the investigation. Data was tabulated, analysed and displayed. Analysis tools include tangent drawing, gradient calculation, smoothing and integration to obtain areas under graph lines etc. Overall this proved very straightforward to use.

8.7 Fourier Nova 5000

8.7.1 Fourier Nova 5000 EX

Width	237 mm at widest
Height	186 mm
Depth	44 mm including feet
Weight	1091 g (1225 g with battery)
Memory	64 Mb RAM and 128 MB NAND flash memory
Screen size	155 mm by 93 mm The very large screen gives a very effective direct display.
Carry case	A carry case is available with holes for the screen and sensor links The base has two folding stand supports for desktop use

Ports	Top vertical face – 4 sensor ports, audio in / out and power jack socket and flashcard slot. Left hand vertical face – USBs for connecting to another computer and printer (or external keyboard). Right hand vertical face – USBs for connecting to printer (or external keyboard) and network connection port.
Battery	Rechargeable NiMH battery pack with lithium backup battery. Charging is either from mains or when connected to computer. The battery should last at least a day in field use (though this depends on which sensors are being used) and takes a few hours to recharge.
Wireless connection	The EX model is wifi enabled. The SX and BX are not.
Manual	It comes with Quick-start and Multilab guides giving clear instructions on using the Nova 5000 as a stand-alone device or linked to a computer.
Upgrades	Upgrades are available from the web site.
Weather proofing	The Nova 5000 is not waterproof. In the field users are advised to store in a waterproof carry case.
‘Field’ use	The Nova is portable but is larger and quite a lot heavier than most loggers tested and cannot be held in one hand easily for use in the field.
Operation	This neat datalogger can be used a stand-alone device to record, analyse and display data or as an interface to another computer. As with a number of similar instruments this is in effect a small computer in its own right.

Operation (continued)	Installation of the USB driver from CD supplied before charging is easy and quick. There is a built in temperature sensor giving ambient temperature readings and a built in microphone and sound sensor. Access is by a start button and navigation is by a keypad below the screen, which proved easy to follow. Power saving operates – restart is from any button. Sensors are easily connected via leads and are instantly recognised by the logger. Several sensors can be tracked at the same time. The remaining keys access the menu, edit and zoom facilities. The touch-screen is operated by a stylus and gave a rapid response. The menu offers continuous logging, individual readings (e.g. at specific events) or snapshot logging. The start button operates logging which can be tracked by a meter or a graphical display on the good-sized screen. The graph autoscaled on both axes where necessary to accommodate the data collected. Several runs may be collected and displayed together if required. Snapshot mode allows sensor readings to be captured on demand and now the data is readily stored in the memory. There is a default setting for straightforward logging operating for 50 seconds but the recording period and frequency of readings were easily altered to suit the investigation, e.g. for very fast or much slower sets of changes. Data may be tabulated, analysed and displayed. Analysis tools including graphing, gradients, differences, area etc. It proved straightforward to modify the table of data and to add notes on activities via an on-screen keyboard. There is also a facility to add pictures. The menu also offered a stopwatch facility, a scientific calculator, a range of experiments and access to a periodic table display. As an alternative the data was saved to a separate computer using the Multilab software and analysed there. It is possible to connect the Nova 5000 direct to a printer without linking to a separate computer. It is also possible to link directly to a projector or whiteboard. In general the Nova 5000 EX also has extensive possible uses outside the science curriculum with a range of facilities such as word processing, spreadsheets etc. The BX and SX have modified software and cater for less demanding curricular needs. The BX is classed as an entry-level model whilst the SX is designed more for scientific use. Fourier, like other suppliers, produces a series of books of experiment suggestions relevant to different aspects of science. Each book comes with a CD version. Whilst these are written for the American market, many of the ideas could be adapted for local curriculum needs.

Fourier also offers the Ecolog XL with 5 built in sensors which is mainly aimed at primary work but might be suitable for some lower secondary work. This machine was not available for testing.

Costs

Supplier	Catalogue number	Price
Fourier	Nova 5000 EX	£299.00*
	Nova 5000 SX	£249.00*
	Nova 5000 BX	£199.00*
Newton Resources	Nova 5000 EX	£299.00

* Excluding carriage

8.7.2 Fourier Sensors

Environmental Parameter	Comment
Air pressure (barometer)	The DT015 can be used as a pressure sensor and an altimeter as well as a means of measuring barometric pressure. The range is 150 to 1150 mbar to an accuracy of +/- 15 mbar.
Carbon dioxide	The carbon dioxide sensor operates over a range of 0 to 5,000 ppm of carbon dioxide (+/- 10%). The sensor consists of an infrared source and a detector and is based on the absorption of infrared light by carbon dioxide. This was not tested.
Colorimeter	DT185A was not tested but is supplied with three colour filters (blue, green and red) as is the cuvette. The absorbance range is 0.05 to 0.7 and transmittance from 20% to 90%, i.e. not quite the same range as many colorimeters.
Conductivity	DT035A is comprised of a conductivity electrode, an adapter equipped with an offset calibration screw and connecting link. It covers the range 0 to 20 mS with an accuracy of about 1 % which is good enough for salinity and water pollution testing. It was not tested
Light	There are several light sensors. The DT009-1 has a single range of 0 to 300 lux and gave a suitably rapid response. Perhaps slightly more useful in environmental monitoring, at little greater expense, is the triple range DT009-4 which covers 0 to 600 lux, 0 to 6,000 lux and 0 to 150,000 lux. A small switch on the body of the sensor enabled rapid movement between the ranges. It proved useful in both indoor and outdoor measurements and gave a rapid response. The DT010, which may still appear in some catalogues, has been discontinued.
Oxygen	The DT222A comprises an oxygen sensitive electrode and a small processing “box” which has a calibration knob. The sensor is designed to measure the % oxygen in air (up to 25%) and % and concentration of dissolved oxygen in aqueous solutions. The range is selected via the Multilab software. Spare membranes, electrolyte solution and bottle are included. As with most oxygen sensors the process needs considerable time and care.
pH	The DT016 has the usual 0 to 14 pH range (accuracy +/- 2%) and includes both an egg shaped adapter and pH electrode at a very competitive price. The sensor has a built in temperature compensation system. The electrode maintenance and storage requires the usual precautions.
Relative humidity	The DT014 covers the range of 0 to 100% relative humidity (accuracy +/- 5 % at near room temperature). The standard egg shaped case needs a separate lead to connect to the logger and is equipped with a zero offset screw. Response rates for humidity sensors are often on the slow side but this modestly priced one was no slower than most.
Soil moisture	DT171A is also a new addition and consists of a detector, an adapter and a cable. The soil moisture content is measured via a small cylindrical detector and ranges from 0 to 2 bar. It was not tested.
Sound	DT320 covers the usual range from 45 to 110 dB and gives a satisfactory response rate and sensible readings.
Stream flow	DT 254A was not tested but is a relatively new model that has a telescopic handle and with the impeller housed in a protective cylinder.
Temperature	The DT029 has a range of -25 °C to 110 °C (accuracy of +/- 1 °C) and plugs directly into the Nova 5000. The 130 mm metallic rod is resistant to mild chemical solutions and should be suitable for most in-door and outdoor environmental investigations. It gave a reasonably rapid response.

Costs

Sensor	Supplier	Catalogue number	Cost
Barometer (air pressure)	Fourier	DT015	£38.00
	Newton Resources	0-1150 mbar	£32.00
Carbon dioxide gas	Fourier	DT040	£95.00
	Newton Resources		£99.00
Colorimeter (sensor only)	Fourier	DT185A	£39.00
	Newton Resources		£39.00
Conductivity adapter including electrode	Fourier	DT035A	£49.00
	Newton Resources		£49.00
Light sensor	Fourier	DT009-1	£22.00
		DT009-4	£25.00
	Newton Resources		£26.00
Oxygen / dissolved oxygen adapter and electrode	Fourier	DT222A	£95.00
	Newton Resources		£99.00
pH adapter and electrode	Fourier	DT016A	£39.00
	Newton Resources		£49.00
Relative humidity	Fourier	DT014	£29.00
	Newton Resources		£31.00
Soil moisture	Fourier	DT171A	£49.00
	Newton Resources		£49.00
Sound	Fourier	DT320	£46.00
	Newton Resources		£46.00
Stream flow rate	Fourier	DT254A	£147
Temperature	Fourier	DT029	£12.00
	Newton Resources		£14.00

There are a number of other sensors for the logger including a range of ion-selective sensors suitable for water quality measurements and a turbidity sensor, but many of the others are not relevant to a study of environmental factors. Nevertheless, the full range should be taken into account when deciding about which logger and which sensors to buy.

Fourier like some other suppliers offer ‘bundles’ – that is packages with a logger and certain sensors – at somewhat reduced rates. These may be helpful provided that all of the items are ones that the school needs.

8.7.3 Fourier Multilab software

Compatibility	Mainly compatible with Windows XP but may work with 98 and 2000 but not at present with VISTA.
Licence	Various licences are available and can be arranged to suit school requirements.
Installation and operation	The Quickstart guides provided did not make clear how the connection to a PC could be easily achieved. The Nova web site provided some help but did not make clear that the Nova 5000 drivers must be downloaded first. Once this had been done, the connection was effective and environmental investigations could be readily controlled via the PC and downloaded data could be analysed as easily as on the Nova direct. The opening screen as usual offered the same range of icons as those on the Nova. As before the sensors were instantly recognised on screen. The menu offered the same range of continuous logging, individual readings (e.g. at specific events) or snapshot logging. The start button operated logging which was tracked on screen. The graph autoscaled on both axes where necessary to accommodate the data collected. Several runs were collected and displayed together. Snapshot mode allowed sensor readings to be captured on demand and the data readily stored. As before there is a default setting for straightforward logging operating for 50 seconds but the recording period and frequency of readings were easily altered to suit the investigation. The start icon operated logging which was tracked by a meter or a graphical display on screen. The graph autoscaled to accommodate the data collected. Several runs were collected and displayed together. Data may be tabulated, analysed and displayed. Analysis tools included graphing, gradients, differences, area etc. It proved straightforward to modify a table of data and to add notes on activities via an on-screen keyboard. As on the Nova 5000 there is a facility to add pictures. The menu again offered a stopwatch facility, a scientific calculator, a range of experiments and access to a periodic table display. Overall this software proved straightforward to use once installed.

8.8 ITEC XLlogger

8.8.1 ITEC XLlogger

The XLlogger came on to the market during the latter half of 2008. It is an entirely different approach to the other systems described above in that it does not need a logger at all. It does, however require use of a PC, laptop or mini notebook into the USB port of which a USB sensor is plugged directly. This has the advantage of saving the cost of buying a logger together with any licences required. It should be noted that the software is relatively expensive although the price includes the appropriate licence. Investigations in a laboratory can be conducted as normal. However, field use becomes far more limited with the necessity to carry the computer to all locations where investigations are to take place. The logistics would also preclude the majority of remote logging investigations.

Costs

Item	Supplier	Catalogue number	Cost
XLlogger software including school site licence	ITEC	XLC2001	£295.00 (£495.00 for FHE Institution)
XLlogger USB 4 port hub	ITEC	XLC6001	£15.44

8.8.2 ITEC XLlogger software

Compatibility	The guidance leaflet indicates that the software works with any version of Excel that may be on the PC, laptop or mini notebook being used. In practice it seems to operate for any Excel version from 2000 onwards. In order to ensure that it works with VISTA, the directions given on the CD-ROM must be followed exactly and security disabled.
Installation and operation	The fact that, with an appropriate version of Excel, no logger or other instrumentation is required is an advantage. Familiarity with Excel and its operation or more explicit guidance notes would be a considerable advantage. Once installed a set of Quick start instructions may be downloaded. It would be advantageous for these to have been available in hard copy prior to installation. When a sensor is connected the software automatically installs the appropriate drivers and there is on-screen recognition of the sensor which is then ready for use. Once access to the software has been achieved the toolbars displayed provide a fairly typical range of choices. The main operational ones include: Autolog in which readings are taken every 0.5 seconds for an indefinite period; Logging settings in which it is possible to physically change the duration and frequency of readings (and add graph titles); Snapshot where time is not a variable and readings may be taken and labelled at the discretion of the observer. Other options include Replay, where the results can be reshown, Repeat when another run can be carried out and Display options where choices can be made about the type of display required (e.g. digital, full screen, etc). A graph format toolbar is separately available giving options to display a graph plot with or without data points, data points only, a bar chart in vertical or horizontal mode, a pie chart, scales, etc. Option for interpretation of graphs obtained include the usual ones such as identification of values at given cursor points, averaging, smoothing of graph plots, gradients at specified cursor points, the area under a graph line, etc. Under test with a variety of sensors in place the screen flickered rather distractingly as each reading was recorded. This is partly attributable to the Microsoft system. The flicker was less intrusive at lower recording rates. The graph autoscaled as the investigation proceeded and tabular information was presented on the screen simultaneously. Use of a four way USB hub enables more than one sensor to be used concurrently. As each new sensor is inserted Microsoft automatically recognises it and requires driver installation. Once the sensor has been used by the computer and the appropriate driver installation has taken place, subsequent use is automatic. When two sensors were plugged in to the hub it proved necessary to switch off Excel and reopen and to use the fresh start button to ensure that both sensors were identified. The graph facility gave the option of having the y axis on the same side or on opposite sides of the graph. Up to four sensors can be operated simultaneously and the results graphed, but choices have to be made as to which axes are displayed. Because a standard Microsoft system is used, saving of experiment result files and transfer, for example to pupils' computers, would be easy. As noted above there are also advantages to the simplicity of the system but the need for a computer would limit use in the field.
Updates	The system is new but as the software is updated the company intends to replace that held by existing users free of charge.

8.8.3 ITEC Sensors

Environmental Parameter	Comment
Gas pressure sensor A	This is designed as a general pressure-measuring device covering the range -100 kPa to 300 kPa. On testing changes in external gas pressure were rapidly recorded and within anticipated ranges.
Light	The XLS1033 operates over a full range of 0 to 15,000 lux though it does so in three bands (0 to 600 lux, 0 to 6,000 lux and 0 to 15,000 lux) making it a suitable all-purpose sensor. On testing there was a distinct time lag between changes in light intensity and the recorded response but test results were within the expected range.
Notes	Sensor packages did not carry information notes. On occasions these would have proved helpful.
Oxygen	The XLS1047 was not tested but is designed to measure gaseous oxygen concentration in the range 0 to 100%. It should be suitable for a range of environmental investigations including photosynthesis and respiration.
pH	The XLS1005 operates over the usual pH range of 0 to 14. The design is typical of glass pH electrodes and the bulb has to be stored in what is presumably a buffer solution. Response was as expected and pH values recorded were within the anticipated ranges.
Relative humidity	The XLS1008 covers the full range 0 to 100% with a resolution of 0.1%. Under test, results were within the expected range but response rate was on the slow side.
Sound	This sensor has a good range from 40 to 110 dBA. It provided a rapid response rate and sensible values to investigations of domestic noises and to simple environmental situations.
Temperature	The stainless steel thermistor sensor operates over the range -25 °C to 125 °C (+/ - 0.1°C) and showed a suitably fast response time under test. It should not be used in corrosive, especially acidic, solutions.

Costs

Sensor	Supplier	Catalogue number	Cost
Air pressure	ITEC	XLS1032	£72.35
Light sensor	ITEC	XLS1033	£37.44
Oxygen gas	ITEC	XLS1047	£99.45
pH sensor	ITEC	XLS1005	£72.35
Relative humidity	ITEC	XLS1008	£62.01
Sound	ITEC	XLS1013	£38.03
Temperature	ITEC	XLS1001	£28.67

There are a number of other sensors for the system, though the range is not yet as extensive as more established systems. Most of the other sensors available at the time of writing are not relevant to a study of environmental factors. Nevertheless, the full range should be taken into account when making decisions about which system and which sensors to buy. ITEC has a number of other sensors under development, some of which would be relevant to environmental investigations, including carbon dioxide, dissolved oxygen and a colorimeter.

After purchase support for all logging systems

As with all new equipment, or equipment which is new to the teacher, spending time with the instruction leaflet, the loggers, the software and the sensors is essential. Whilst there are similarities between models from different companies there are usually some very different characteristics as well. Most of the suppliers will provide some post-purchase training, which may be free but may be charged for. All offer post-purchase support, which is reportedly very helpful.

Appendix 1 Manufacturers and suppliers addresses

Beecroft & Partners Ltd
Northfield Road
Rotherham, South Yorkshire
S60 1RR
Tel: 01709-377881
Fax: 01709-369264
email: sales@beecroft-science.co.uk
website: www.beecroft-science.co.uk

The Consortium
Hammond Way
Trowbridge
Wiltshire, BA14 8RR
Tel: 0845 33097780
Fax: 0845 3307785
email: enquiries@theconsortium.co.uk
website: www.theconsortium.co.uk

Datadisc
See Sciencescope

Data Harvest Group Ltd
1 Eden Court
Leighton Buzzard
Bedfordshire, LU7 4FY
Tel: 01525 373666
Fax: 01525 851638
email: sales@data-harvest.co.uk
website: www.data-harvest.co.uk

DCP Microdevelopments Ltd
Bryon Court, Bow Street
Great Ellingham
Norfolk, NR17 1JB
Tel: 01953 457800
Fax: 01953 457888
email: info@dcpmicro.com
website: www.dcpmicro.com

Feedback Instruments Ltd
Park Road
Crowborough
East Sussex, TN6 2QR
Tel: 01892 653322
Fax: 01892 663719
email: sales@fdbk.co.uk
website: www.fbk.co.uk

Fisher Scientific
Bishop Meadow Road
Loughborough
Leicestershire LE11 5RG
Tel: 01509 231166
Fax: 01509 231893
email: sales@fisher.co.uk
website: www.fisher.co.uk

Fourier Systems UK Ltd
PO Box 402, Maghull Business Centre,
Red Lion Building, Liverpool Road North
Maghull, L31 2HB
Tel: 0845 434 7934
Fax:
email: ukinfo@fourier-sys.com
website: www.fourier-sys.co.uk

Granet Science
PO Box 404
Aylesbury
Buckinghamshire, HP19 9WD
Tel: 01296 398624
Fax: 01296 426507
email: sales@granetscience.co.uk
website: www.granetscience.co.uk

Greater London Supplies (GLS Fairway)
1 Mollison Avenue
Enfield,
Middlesex, EN3 7XQ
Tel: 0845 1203213
Fax: 0800 9172246
email: sales@glsed.co.uk
website: www.glsed.co.uk

Griffin Education
Bishop Meadow Road
Loughborough
Leicestershire LE11 5RG
Tel: 01509 233344
Fax: 01509 555200
email: griffin@fisher.co.uk
website: www.griffineducation.co.uk

IDS (Instruments Direct Services Ltd)
Unit 8, The Courtyard
Stenson Road, Coalville
Leicestershire, LE67 4JP
Tel: 01530 832500
Fax: 015300817087
email: sales@inds.co.uk
website: www.inds.co.uk

ITEC Ltd
Holloway House, Marlcliff
Bidford on Avon
Warwickshire, B50 4NU
Tel: 01789 773537
Fax: 01789 490832
email: pgodding@itec-education.co.uk
website: www.itec-education.co.uk

NES Arnold
Gregory Street,
Hyde,
Cheshire, SK14 4SG
Tel: 0845 120 4525
Fax: 0800 328 0001
email: enquiries@nesarnold.co.uk
website: www.nesarnold.co.uk

Newton Resources
Century House
Station Road, Sheffield
Yorkshire, S20 3GS
Tel: 0114 3240035
Fax: 0114 3240025
email: info@newtonresources.co.uk
website: www.newtonresources.co.uk

Philip Harris Ltd
Hyde Buildings
Hyde
Cheshire
SK14 4SH
Tel: 0845 1204520
Fax: 0800 1388881
email: customerservice@philipharris.co.uk
website: www.philipharris.co.uk

RapidElectronics
SeverallsLane
Colchester
Essex, CO4 5JS
Tel: 01206 751166
Fax: 01206 751188
email: sales@rapidelec.co.uk
website: www.rapidonline.co.uk

RM
New Mill House, 183 Milton Park,
Abingdon,
Oxfordshire, OX14 5SE
Tel: 08450 700300
Fax: 08450 700400
email: secondarysales@rm.com
website: www.rm.com

Sciencescope
Abington House
146 London Road West
Bath, BA1 7DD
Tel: 0870 2256175 or 01225 850020
Fax: 01225 850029
email: sales@auc.co.uk
website: www.sciencescope.co.uk

Scientific & Chemical Supplies
Carlton House
Livingstone Road
Bilston
WV14 0QZ
Tel: 01902 402402
Fax: 01902 402434
email: info@scichem.com
website: www.scichem.com

TAG (encompassing Economatics)
25 Pelham Road
Gravesend
Kent, DA11 0BR
Tel: 01474 357350
Fax: 01474 537887
email: sales@taglearning.com
website: www.taglearning.com

Timstar Laboratory Suppliers Ltd
Timstar House
Marshfield Bank, Herald Drive
Crewe, Cheshire, CW2 8UY
Tel: 01270 250459
Fax: 01270 250601
email: sales@timstar.co.uk
website: www.timstar.co.uk

TTS Group Ltd
Park Lane Business Park
Kirkby-in-Ashfield
Nottinghamshire, NG17 9LG
Tel: 0800 318686
Fax: 0800 137525
email: sales@tts-group.co.uk
website: www.tts-group.co.uk

Vernier International
See IDS

Yorkshire Purchasing Organisation (YPO)
41 Industrial Park
Wakefield, Yorkshire
WF2 0XE
Tel: 01924 824477
Fax: 01924 834805
email: sales@ypo.co.uk
website: www.ypo.co.uk